Pesticide Residues in Food and Biological Tissue

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Indian National Science Academy
New Delhi

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A Report of the Situation in India

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PREFACE

Extensive work has been carried out in India on pesticide residues in a variety of foods. The subject has been discussed in a few national symposia and has been dealt with very often in the media. The data scattered in several journal and reports was collected with commendable patience by my former colleagues Shri R R Khan, Shri Bhasker Dev and Kumari Gomti Iyer of Industrial Toxicology Research Centre, Lucknow. This status report, based on that literature survey, is a review of the work on pesticide residues. But for their painstaking efforts it would not have been possible for me to accomplish this task on behalf of the Indian National Science Academy in its Golden Jubilee Year.

There are several aspects of pesticide research other than residues which are of equal concern to us, Research and Development efforts in India are largely confined to the development of indigenous technology for the manufacture of pesticides and their formulations, discovery of safer pesticides and the field testing of the efficacy of various pesticide formulations. There are some recent studies on the use of biological agents such as the larvicidal activity of *Bacillus thuringensis*. Basic studies on biological control, mechanism of pesticidal action, the molecular biology of the malarial or filarial parasite in relation to the insect vector or the comparative biochemistry of arthropods and other pests are areas of basic research which, in spite of their immediate relevance, have not attracted the attention they deserve. No wonder there is no concerted effort to introduce Integrated Pest Management Programmes. It is also not comforting to remind ourselves that interesting leads on biological control of vectors gained during the sixties have been lost.

The discriminate use of man-made chemicals appears to be unavoidable in the foreseeable future in the agriculture and public health sectors, and as such there is need to pay more attention to their safety aspects. It is hoped that this status report will be of some use to those concerned with the safety of pesticides and in regulating their use and diffusion in the environment.

I am indebted to Shri R R Khan, Shri Bhasker Dev and Kumari Gomti Iyer for their help in preparing this review. My grateful thanks to Prof A K Sharma, President, Indian National Science Academy for critically reading the typescript and writing a foreward and to the Department of Environment, Government of India for the award of the Pitamber Pant National Fellowship for working on projects related to ecotoxicological problems of relevance to India.

March 3, 1984 *C R Krishna Murti*

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1. Introduction

1.1 The Era of Pesticides

Pesticides came into extensive use in agriculture and public health in the early forties of this century. Enhanced farm productivity and inexpensive control of vector-borne diseases were the main benefits brought by pesticides. These made a great impact on the production and storage of food, fibre and other cash crops. The incidence of malaria was dramatically reduced in India from 7—10 million reported cases in 1947 to less than 100,000 in 1965. Chlorinated pesticides such as DDT, dieldrin and mirex were hailed with great acclaim as the harbingers of a new era of freedom from hunger and pestilence.

1.2 Adverse Side Effects of Pesticides

Soon, however, increasing evidence began to appear that residues of chlorinated pesticides remained in the environment and accumulated in plants and animals. A number of side effects due to the unforeseen biological activities of these chemicals were noticed which included sickness and death in humans, animals, fish and birds. By the late seventies some pesticides attained a degree of notoriety which led to their use being banned in some developed countries.

1.3 Global Use Pattern

The above experience notwithstanding, control of plant pests globally and vectors of diseases in the developing countries has depended, in the last three decades, almost entirely on the use of chemical pesticides. Near about 250,000 tonnes of pesticides and their formulations equivalent in value to over five billion US dollars are used every year all over the world. These include a thousand and odd individual chemical entities in the form of diverse formulations (Krishna Murti & Dikshith 1982). The sheer volume of the trade in pesticides and the urgency of increasing food production at any cost have unfortunately tended to influence the attitude of policy makers to the safety of these chemicals which are best described as "double-edged" weapons (Krishna Murti 1983).

1.4 Indiscriminate Use of Pesticides

The indiscriminate use of pesticides can be considered as one of the most hazardous operations which pose potential threat to our living environment. In fact a summary report of the United Nations Environment Programme (UNEP) for the year 1979 paraphrazed the overall environmental impact of pesticides in the following words :

> "When carelessly applied, chemical pesticides can result in acute and long term side-effects including sickness and death of people, useful animals, fish and birds, and destruction of crops. Even when properly used, chemical pesticides have a number of unavoidable side-effects. Their persistence and ubiquitous

> nature, combined with a tendency of some compounds to concentrate in organisms as they move up the food chain, may increase their toxicity to fish, birds and other forms of life including man, and cause other harmful effects on man's health and well-being."

A World Health Organization report issued in 1979, dealing specifically with the metabolism and effects in experimental animals and man of DDT makes the following important inference :

> "The information derived from human exposure is insufficient to construct a comprehensive picture of the dosage-effect relationships for man except in connection with storage and excretion of the compound and its metabolites."

The Ninth General Assembly of UNEP held at Nairobi in 1980 expressed serious concern of the global impact of the spread of persistent chemicals in the environment. The Assembly directed the International Register of Potentially Toxic Chemicals (IRPTC) to identify on a priority basis a list of chemicals and chemical processes which constitute potential danger to human welfare in the present context and in future. A panel of experts constituted by IRPTC drawn from all over the world met at Geneva in November 1981 and after extensive discussion of background papers, included the "indiscriminate use of pesticides" among the four activities of global concern involving the diffusion in the environment of toxic chemicals with long-term consequences on human welfare. Accordingly, UNEP requested member nations to examine more critically their current programmes of vector control and plant protection based on non-degradable pesticides.

1.5 Guidelines for Limits of Pesticide Residues

The Codex Alimentarius Commission set up jointly by FAO/WHO as part of their Food Standards Programme prepared a guide in collaboration with UNEP to derive maximum limits for pesticide residues in food products and feeds (FAO/WHO, 1978). The preamble statement of this document states:

"At present alternative methods of pest control are not available to the extent that they can be applied on a broad scale as full replacement of pesticides, but they offer possibilities in specific cases, either alone or in combination with selected or selective pesticides.

"Research on alternative methods of pest control to be applied in combination with selected or selective pesticides (i.e. integrated pest control) should, therefore, be intensified, and in the meantime emphasis should be placed on a system of supervised control, which aims at a judicious use of pesticides coupled with assessment of economic threshold levels and forecasting systems.

"Pesticide legislation or other effective control systems should be introduced and implemented in those countries where they have not yet been established; in other countries with existing legislation or administrative controls, these may need be intensified in order to strike a better balance of benefits to agriculture against risks to humans, environment and food."

1.6 The Current Pesticide Situation

The complexity of the pesticide situation is brought out in Figure 1. On the credit side one can enlist the following:

a) The use of pesticides has decreased the extent of vector-borne diseases in humans and animals.

b) The use of pesticides has minimised losses of food caused by pests and ensured a better protection of harvest than was possible hitherto.

c) The use of pesticides has increased the quantity of food.

On the debit side one must mention the following:

a) Occupational exposure to pesticides during manufacture, formulation and application has resulted in illness and accidents leading to death.

b) Pesticides have been misused in many countries for an increasing number of suicide and homicide.

c) The regular use of pesticides is not free from side effects, the most important of which is the accumulation of residues.

d) Repeated application of pesticides has led to development of resistance by plant pests and insects causing concern to both management of plant protection as well as vector control in public health (FAO 1976, WHO 1980),

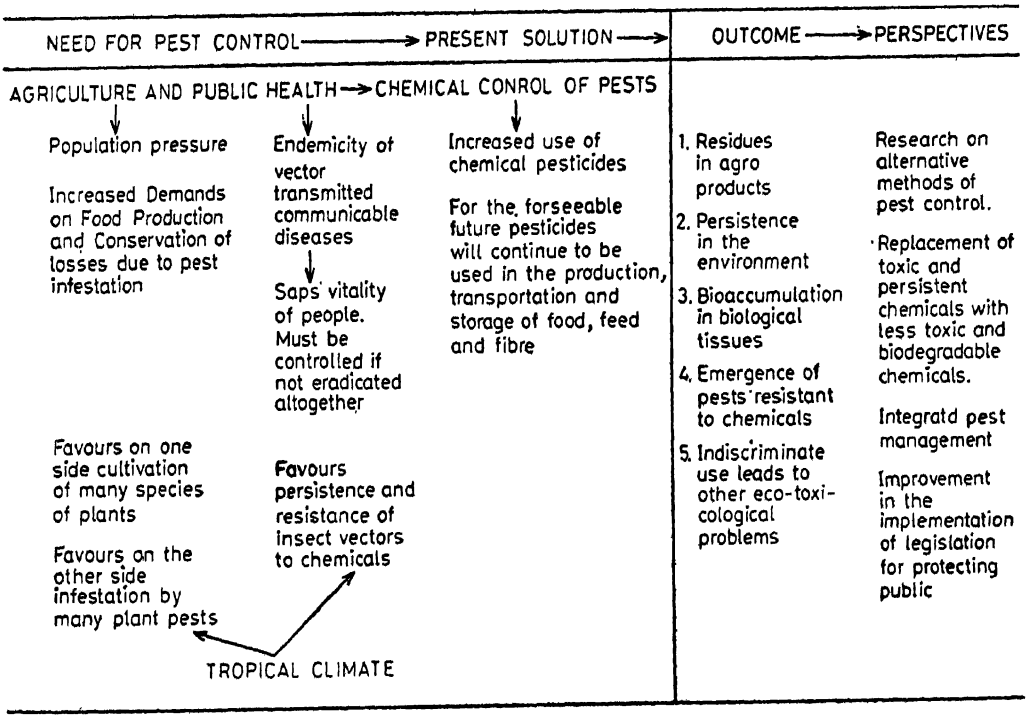
NEED FOR PEST CONTROL → PRESENT SOLUTION →
OUTCOME → PERSPECTIVES
AGRICULTURE AND PUBLIC HEALTH → CHEMICAL CONROL OF PESTS
Population pressure
Increased Demands on Food Production and Conservation of losses due to pest infestation
Endemicity of vector transmitted communicable diseases
Saps vitality of people. Must be controlled if not eradicated altogether
Increased use of chemical pesticides
For the forseeable future pesticides will continue to be used in the production, transportation and storage of food, feed and fibre
1. Residues in agro products
2. Persistence in the environment
3. Bioaccumulation in biological tissues
4. Emergence of pests resistant to chemicals
5. Indiscriminate use leads to other eco-toxicological problems
Research on alternative methods of pest control.
·Replacement of toxic and persistent chemicals with less toxic and biodegradable chemicals.
Integratd pest management
Improvement in the implementation of legislation for protecting public
Favours on one side cultivation of many species of plants
Favours on the other side infestation by many plant pests
Favours persistence and resistance of insect vectors to chemicals
TROPICAL CLIMATE

Figure 1 The pesticide situation today

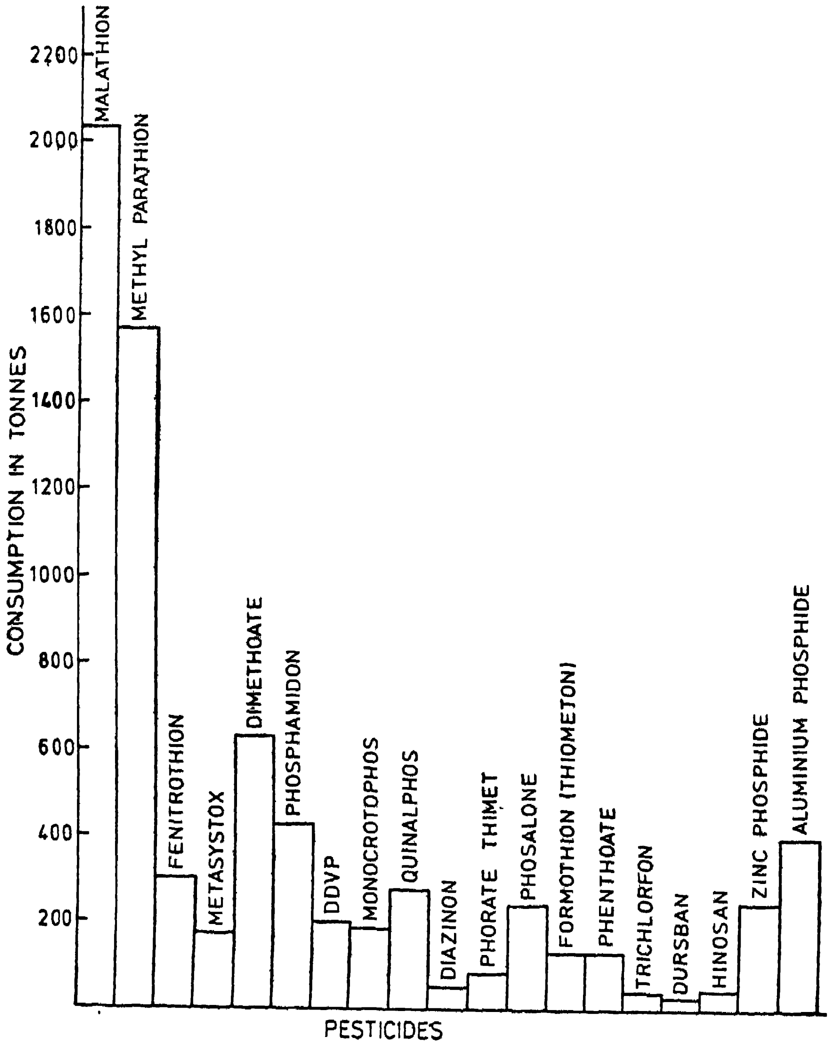

Figure 2 Estimated consumption of pesticides based on import/production for 1977-78

Literature on pesticide residue studies is reviewed in this report against the background of the production and use pattern of pesticides in India. Some other publications of relevance to this topic are (Matsumura & Krishna Murti 1982; Tulpule et al. 1982, Attri et al. 1981). While every effort has been made to cover all the studies reported from India, it is likely that inadvertantly some have not been included. Residue levels in plantation crops such as tea, coffee, cardamom and in cultivated medicinal and aromatic plants shall be dealt with in a later publication.

2. Pesticides—Production and Use Pattern in India

2.1 Food Loss by Pest Infestation

The varied tropical and sub-tropical climatic condition characteristic of the Indian subcontinent and the diversity of the vegetable kingdom are conductive for the propagation of innumerable plant pests. The ravages wrought by them on the productivity of our land are reflected in the loss of valuable food and fibre crops. For instance, in the period 1976-77 these losses were 47, 28, 24 and 25% for groundnut, cotton, rice and sugarcane or, in other words, 20% of the cropped area of that duration was affected by preventable diseases. The average annual loss of the gross output of agricultural products is estimated at 10-15% (Government of India, 1981).

On a global scale, insects were found in a 1947 FAO survey to destroy up to 5% of the world production of cereal grains. In 29 countries included in the survey, the loss of cereals was 23,355,000 tonnes, of which 50% was due to insect infestation (Cotton & Ashby 1952).

2.2 Arthropod Pests as Vectors of Communicable Diseases

Besides frustrating our efforts to raise farm productivity, some pests function as vectors for the spread of diseases like malaria. filaria, encephalitis and kala azar. Whereas pests which attack plants belong to diverse genera and species and constitute thousands in number, the vectors of concern to public health are limited to a few arthropod species. This difference has to be kept in mind while discussing pest control strategy in the agricultural sector as opposed to the public health sector.

2.3 Pattern of Use in India

Control of vectors of piseases with chemicals in India began soon after the World War II. Taking the figures for 1973-74, the use of pesticides per acre of cultivated land in India was relatively low (see Table 1) as compared to Japan or USA. Nevertheless, there was a thousand-fold increase in the application rate from less than 400 mg/ha in 1968 to 336 g/ha in 1973-74. Table 2 gives an idea of the consumption of

Table 1 *Pesticide application in some countries of the world (1973–74 figures)*

Country	Pesticide use/ha (in g)
Japan	10,790
Europe	1,870
USA	1,490
India	336 (400 mg in 1968)
Africa	127

Table 2 *Consumption of pesticides (technical grade) in India 1965–1980 (in tonnes)*

Year	Agricultural sector	Non-agricultral sector	Total
1965-66	6654	7976	14630
1966-67	7442	9695	17137
1967-68	11206	9695	20907
1968-69	14098	14102	28200
1969-70	11844	14156	26000
1970-71	10164	14156	24320
1971-72	19935	9600	29535
1972-73	25076	10084	35160
1973-74	31863	13137	45000
1974-75	37523	12341	49864
1975-76	43414	15400	58814
1976-77	36713	15205	51918
1977-78	39830	19100	58900
1978-79	NA	NA	47730
1979-80	25000	18000	43000

(Source: *Pesticides Annual 1980–81*)

Table 3 *Cropwise Consumption of Pesticides 1978–79 (estimates) in tonnes of technical grade material*

a) *Food Crops*	
Paddy	33315.20
Wheat	25784.10
Maize	2380.20
Jowar	4830.30
Bajra	6450.40
Pulses	7283.10
b) *Cash Crops*	
Sugarcane	7210.40
Cotton	8431.60
Jute	640.10
Oilseeds	44910.60
Fruits, plantation & others	4205.00
c) *Vector Control*	35,000 (anticipated)

(Source: *Report of the national Commission on Agriculture, 1976, Part X Inputs*)

Table 4 *Production of Pesticides in India 1966-79*

Year	Production (in tonnes)
1966	14,000
1968	15,849
1970	27,338
1971	24,687
1972	26,716
1973	31,650
1974	32,950
1975	35,230
1976	34,705
1977	39,600
1978	49,847
1979	50,041

(Source: *Pesticides Annual 1981–82*)

technical grade pesticides in the agricultural and non-agricultural sectors from 1965t o 1980. Figure 2 illustrates the variety and quantity of pesticides consumed in 1978-78. Cropwise consumption (in tonnes) of technical grade pesticides for the year 1978-79 was 80,073 for food crops and 65,398 for other crops whereas for the health sector the figure was 35,000 (see Table 3).

2.4 Manufacture of Import and Pesticides

Indigenous manufacture of pesticides began in India in 1958 with the setting up of a plant for benzene hexachloride (BHC) followed by DDT. Today more than 122 pesticides including synthetic pyrethroids are registered in the country. About 200 units in the small scale or unorganized sector undertake the manufacture of conventional formulations, mainly dust, wettable powder and emulsifiable concentrates. With a total licensed capacity of 77,897 tonnes (the installed capacity was, however, only 50,041 tonnes in 1979), India is the largest manufacturer of basic pesticidal chemicals in the region comprising South Asia and Africa. As evident from the figures

Table 5 *Production figures for individual Pesticides in India 1976–83 (in tonnes)*

Pesticides	1976	1977	1978	1979	1980-81 (Financial Year)	1982-83
1. BHC	23,956	27,356	33,710	34,184	28,760	32,378
2. DDT	4,527	4,240	4,285	4,626	4,004	5,199
3. Malathion	1,750	1,980	2,617	2,622	1,264	4,027
4. Parathion	—	1,401	1,944	—	1,213	3,030
5. Metasystox	1,274	158	212	169	150	896
6. Fenitrothion	—	248	333	436	116	154
7. Dimethoate	350	666	793	793	817	896
8. Phosphamidon	231	342	566	567	451	852
9. DDVP	112	157	211	320	103	174
10. Quinalphos	191	238	380	466	385	605
11. Copper oxychloride	465	943	1,182	1,176	1,147*	1,032
12. Nickel chloride	30	51	48	30	39	—
13. 2, 4-D	201	417	340	290	338	438
14. Zinc phosphide	—	61.5	127	—	197*	302
15. Phenthoate	—	49	124	—	0.6	—
16. Carbaryl	—	321	368	—	1,155*	2,337
17. Aluminium phosphide	605	531	376	—	710*	—
18. Organomercurials (6% and 15%)	54	121	159.5	120	179	147
19. Dithiocarbamates	644**	1,227†	1,714‡	1,720‡ (1979-80)	1,159‡	1,770

* Provisional

** Pertains to only Zineb, Mancozeb, Maneb, Thiram, Ziram

† Pertains to only Zineb, Mancozeb, Maneb

‡ includes all dithiocarbamates

given in Table 4, there was a four-fold increase in the installed capacity from 1966 to 1979. Production figures for some of the commonly used pesticides for the period 1976-1981 are given in Table 5. It would be seen that the production of Parathion, zinc phosphide, phenthoate, carbaryl and aluminium phosphide registered a significant increase in recent years whereas the production of DDT and BHC has almost levelled off after 1976.

Apart from indigenous production, varying quantities of organochlorines, organophosphorous and organometallic compounds are also imported. Values of such imports for the period 1976-1981 are given in Table 6. It is interesting to note that along with indigenous production, DDT continues to be imported although in much smaller amounts. Most of this import is obviously from countries where its use has been banned.

Carbaryl, monocrotophos, paraquat, bavisten etc. are expected to be produced indigenously in the next few years. Further, new pesticides are also being developed by Research and Development efforts in the Indian Agricultural Research Institute, Delhi, Regional Research Laboratories at Hyderabad, Jammu and Jorhat, National Chemical Laboratory, Pune, the R & D centres of Hindustan Insecticides, Union Carbide, Ciba India, Rallis, Multi-chemicals, and Voltas and other multi-national concerns. A comparison between capacity for production of technical grade pesticides and production figures for 1982-83 is given in Table 7.

Table 6 *Quantity of Organochlorine, Organophosphate Pesticides and Organometallic Fungicides Imported during the period 1976–81 (in tonnes)*

Pesticides	Volume of imports				
	1976–77	1977–78	1978–79	1979–80	1980–81
Organochlorine					
DDT	11841.8	7,450	4,618	2,812	1,953
Lindane	11.1	—	25	5	1
Organophosphate					
Chloropyriphos	—	—	—	—	11
Diazinon	7.0	—	27	11	2
Dichlorvos	—	—	2	—	55
Dimethoate	—	—	9	1	5
Methyl parathion	—	36	—	185	298
Monocrotophos	111.89	—	25	75	192
Phenthoate	14.43	—	217	54	55
Phorate	—	—	173	39	15
Phosalone	230.108	—	282	9	37
Tenophos	—	—	—	—	15
Thiometon	—	—	8	15	3
Fungicides					
Dithiocarbamates	—	—	20†	—	26‡

† Pertains to Zineb and Thiram only
‡ Pertains to Thiram only

Table 7 *Installed Capacity and Production of technical Grade Pesticides 1982-83*

	Capacity (Tonnes)	Production (Tonnes)
Insecticides		
(Organo-chlorine compounds)		
BHC	41,900	32,378
DDT	9,144	5,199
Endosulfan	2,400	2,098
Lindane	30	Nil
Total	53,474	39,675
(Organo-phosphorus compounds)		
DDVP	275	174
Dimethoate	1,150	896
Fenitrothion	1,100	154
Malathion	6,490	4,027
Dimethon-o-methyl sulfoxide	250	188
Phorate	1,050	506
Monocrotophos	950	318
Methyl parathion	1,850	3,030
Phosphamidon	836	852
Quinalphos	750	605
Phenthoate	600	Nil
Temephos	25	Nil
Fenthion	200	151
Phosalone	1,000	Nil
Ethion	2 0	9
Total	16,727	10,910
Carbamates		
Carbaryl	7,000	2,337
Total	7,000	2,337
Synthetic Pyrethroids		
Fenvalerate	250	Nil
Total	250	Nil
Others		
Nicotine sulphate	40	Nil
Total	40	Nil
Fungicides		
Copper oxychloride	3,660	1,032
Copper sulphate	3,000	1,500
Nickel chloride	300	Nil
Organo-mercurials	91	147
Dithio carbamate	2,500	1,770
Thiram	400	
Ziram	634	
Ferbam	25	13
Metham sodium	25	
Carbandiazin	335	65
Sulphur	2,040	Nil
Total	13,010	4,527
Rodenticides		
Coumafuryl	50	Nil
Zinc phosphide	1,294	302
Warfarin	50	4
Total	1,394	306
Herbicides/growth regulators		
2, 4—D	1,135	438
Dalapon	250	6
Paraquat	500	478
Propanil nitrogen	1,500	Nil
Fluchloralin	50	45
Diuron	200	23
Ana	5	2
Cycocel	100	77
Total	3,740	1,069
Fumigants		
Aluminium phosphide	1,820	616
Ethylene dibromide	258	56
Methyl bromide	300	30
Total	2,378	792
Grand Total	98,013	59,526

(*From* : P R Sarma Imperatives in Pesticide Promotion; The Hindu Survey of Industry, 1983), Madras

3. Pesticide Residues in the Environment

3.1 Definitions

The following definitions as given in the Guide to Codex Maximum Limits for Pesticide Residues (FAO/WHO, 1978) are adopted in this review:

> *Pesticide residue* means "any substance or substances in food for humans or animals resulting from the use of pesticide". It also includes any specified derivatives, such as degradation and conversion products, metabolites and reaction products which are considered to be of toxicological significance. The term pesticide means any substance or mixures of substances intended for preventing or controlling any pest and includes any substance or mixtures of substances intended for use as a plant growth regulator, defoliant or dessicant. The term excludes fertilizers and antibiotics or other chemicals administered to animals for other purposes such as to stimulate their growth or to modify their reproductive behaviour.
>
> Pesticide residues occur in agricultural commodities as a result of
>
> a) intentional use of pesticides for protection of growing crops or stored products or of animals;
>
> b) unintentional exposure to pesticide such as would occur in crops grown in soil treated previously or contaminated by foliar treatment of other crops grown earlier in the rotation;
>
> c) unintentional accumulation in animals from the ingestion of feeds containing pesticide residues; and
>
> d) contamination of crops or animals exposed to chemicals in the environment.

3.2 Fate of Pesticides in Environment

The fate of pesticides applied for crop protection and vector control in public health is shown diagrammatically in Fig. 3. The compartmentalization in the environmental components is facilitated by the manner of application (sprays mostly) and the chemical nature of the compounds. Pesticidal contamination of the environment is directly related to their persistent nature. The two most important degradative forces operating on chemicals in the environment are micro-organisms and sunlight. This conclusion has been derived on the basis of the following observations:—

—Most pesticides end up in soil

—They are spread in the environment in very low concentrations

—Soil and aquatic media are generally rich in micro-organisms

Depending on their exposure to sunlight many pesticides escape by volatilization into the atmosphere.

It must also be borne in mind that other factors including the redox potential, nutritional state of the soil, *p*H, physical adsorption and absorption and availability of catalysts contribute to the fate of pesticides in the environment (Matsumura 1982).

There is a generally held belief that the loss of organic pesticides by volatilization, photo-decomposition and microbial degradation is more rapid under tropical and subtropical climates than in temperate ones. However, despite the fact that persistent chlorinated hydrocarbons are used extensively in tropical agriculture, information on their residues in the tropical environment is fragmentary making it difficult to attempt any meaningful interpretation of the situation in regard to tropical ecosystems (Bindra & Kalra 1973, Agnihothrudu & Mithyantha 1978, Sethunathan et al. 1982).

3.3 Fate of Pesticides in the Aquatic Environment

Transport and fate of pesticides in the aquatic environment is influenced by their concentration, dilution and degradation. Much of the information now available on the effect of pesticides on aquatic organisms and their environment is in terms of acute toxicity and mortality of individual species associated with aquatic environments.

Microcosms or experimental environments in the laboratories and in field systems of relatively restricted size have proven useful in bioassay studies as well as in exploring their transport, fate and degradation in the environment.

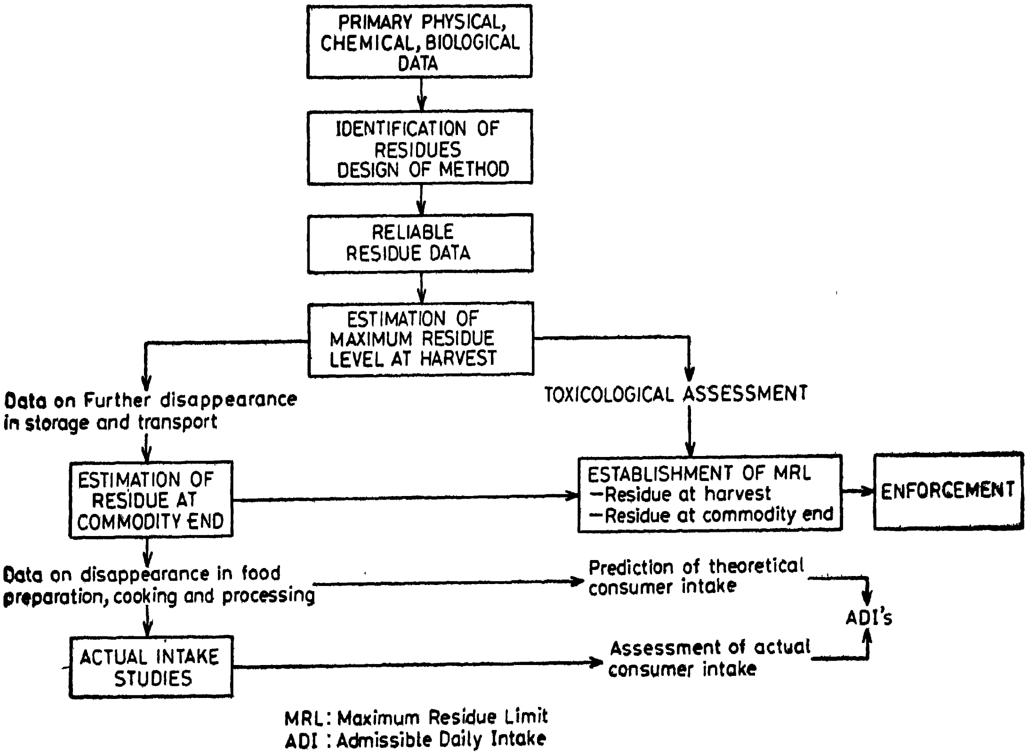
PRIMARY PHYSICAL, CHEMICAL, BIOLOGICAL DATA
IDENTIFICATION OF RESIDUES DESIGN OF METHOD
RELIABLE RESIDUE DATA
ESTIMATION OF MAXIMUM RESIDUE LEVEL AT HARVEST
Data on Further disappearance in storage and transport
TOXICOLOGICAL ASSESSMENT
ESTIMATION OF RESIDUE AT COMMODITY END
ESTABLISHMENT OF MRL −Residue at harvest −Residue at commodity end
ENFORCEMENT
Data on disappearance in food preparation, cooking and processing
Prediction of theoretical consumer intake
ADI's
ACTUAL INTAKE STUDIES
Assessment of actual consumer intake
MRL: Maximum Residue Limit
ADI : Admissible Daily Intake

Figure 3 : Model of an ideal pesticide regulatory system (Adapted from Bates, 1981).

Concentration of DDT in surface water depends on the soil as well as rainfall. Levels of DDT were monitored in water, mud, zooplankton, dead fish muscle and gill tissue in the Sathiar reservoir in Tamil Nadu where both DDT and DDE were detected in relatively high levels (Kannan & Job 1979). However, none of the ten water samples excepting one pond (1.5 ppm) collected from Calcutta Corporation's water supply, guages, deep and shallow tube wells and ponds were found to be contaminated (Mukherjee et al. 1980).

The Arabian sea water was also found to be relatively free from DDT and its metabolities although heavy aquatic fauna collected from the sea showed high residue levels (Sen Gupta et al. 1980).

The analysis of water samples collected from ponds in the coffee estates of Chikmagalur District of Karnataka revealed the presence of HCH from 0.02 to 0.2 ppm. The insecticide was however absent in the silt of the ponds and rivers of this area (Visweshwariah et al. 1976). In another study, from the same region, drinking water was found to contain 0.02–6.16 ppm of HCH (Venkataramaiah & Singh 1973).

Persistence of γ-HCH in water was studied over a period of 28 days, the residue being 5% in tap water at the end and slightly higher in distilled water. The rate of dissipation was very poor if water was kept in a close-mouthed bottle (Mukherjee et al. 1979).

Decontamination of water containing γ-HCH and total HCH was achieved by adding 4% wood charcoal powder with a particle size 35–40 mesh (CFTRI; 1975, Visweswaraiah et al. 1977). Removal of γ-HCH and other organochlorine pesticides was studied using granular activated carbon columns followed by gas chromatography for detection. Removal of γ-HCH to the extent of 99% was noted at 1.26 m/hr loading (Thakkar & Muthal 1980).

3.4 Fate of Pesticides in Soil

The persistent nature of organochlorine pesticides affects crops raised on soil contaminated with pesticides. Type of soils, organic matter content, clay content, *p*H, nature of soil colloids, organisms present in the soil, water and air flow, crop practices, intensity of wind, sunlight and rain affect the persistence of pesticides in the soil.

Work on the persistence of pesticides supported by Indian Council of Agricultural Research has been in progress in many agriculture universities and some research institutions. Farm products collected from Pantnagar in the Nainital District indicated a high level of contamination, 120 out of 138 samples examined showing DDT (Tripathi 1966). Pesticide residues in the soils of Pantnagar farm, kitchen gardens and other non-agricultural land were 15 ppm, 4.4 ppm and 0.65 ppm respectively.

The persistence of HCH and its isomers has been studied in the soil and also in a number of standing crops. When γ-HCH 97.7% (5% dust) was mixed in the top 15 cm of Delhi soil @ 10 kg a.i./ha, it was lost within a period of 6 months (Agnihotri et al. 1977). In contrast, a study carried out in Punjab under various climatic conditions showed that more than 50% of HCH remained in the soil even after a period of 9 months (Chawla & Chopra 1967).

Clay-loam soil treated with different dosages of HCH (5–30 kg. a.i./ha) facilitated a rapid dissipation of the insecticide (Srivastava & Yadav 1977). Adsorption and persistence of γ-HCH studied in red, laterite, black and karl (saline sodic calcareous black cotton soil) of Karnataka indicated that the adsorption of γ-HCH by the soil particles varied from 55% to 100% when the pesticide was added @ 7-35 μg/g of soil Mithyantha 1973). Adsorption was highest in the acidic laterite soil followed by black, red and karl soils. Clay fractions of the soil retained smaller amounts of pesticide than their parent soil. γ-HCH adsorption was highest in calcium-saturated clays. The percentage adsorption decreased with an increase in the dose applied. With increase in temperature, the quantity adsorbed decreased. In a 6 week incubation study with HCH, only 10–15% of the quantity initially added was degraded in the soil. Degradation was faster when the moisture content was increased. Organic matter was responsible for more than 50% of adsorption of γ-HCH. Low sorption of γ-HCH in anaerobic soil containing less organic matter has also been confirmed by other studies (Wahid & Sethunathan 1980).

Rapid degradation of γ and β-HCH in alluvial, laterite and *Pokkali* soil (saline acidic soil rich in organic matter) soil was observed under submerged puddled paddy soil conditions (Siddaramappa & Sethunathan 1975). In sandy and *kari* (acid sulphate) soils, however, both the isomers persisted even after 41 days of flooding. γ-HCH degraded faster than β-HCH. Addition of rice straw to the soil increased the rate of disappearance of both the isomers, providing further evidence that γ-HCH is also lost by volatilization from puddled-soil (Siddaramappa & Sethunathan 1976). An 8 week radioactive tracer study of γ-HCH degradation in soils revealed that approximately 89 and 86% and 84 and 70% of added pesticide could be recovered from moist and submerged organic soils and moist and submerged mineral soils, respectively (Mathur & Saha 1977).

In field experiments involving 3 types of soils of rice-growing fields, HCH was found to have the ability to slow down the process of soil reduction and thus make available important nutrients to the rice plants. Granular HCH was added to these soils at 100 ppm a.i. and the soils were then flooded. The soils receiving HCH retained their original colour even after 15 days (Pal et al. 1980). When γ-HCH was tested in a sandy loam soil under laboratory conditions, the number of bacteria registered an increase but simultaneously the number of fungi and protozoa was reduced. This beneficial effect of HCH has been utilized in increasing the yield of sugarcane belt of North Bihar (Sahi et al. 1976). In another study, γ-HCH was, however, found to have no such effect on soil microflora (Jaiswal 1967).

Dehydrogenase activity, which is a measure of the metabolic activity of soil micro-organisms, was determined in a flooded soil and HCH was found to inhibit this enzymic activity (Chendrayan & Sethunathan 1980).

Among other cyclodiens, aldrin was found to be readily converted to dieldrin. Application of 5% aldrin to green gram led to its conversion to dieldrin, maximum concentration being on 30th day after treatment, 80.8% of the residual dieldrin being degraded during the subsequent 70 days. In a study on Delhi soils, 96.4% each of aldrin and dieldrin and 86.4% heptachlor were lost in 180 days. Conversion of aldrin epoxide was much faster than hitherto reported (Agnihotri et al. 1977).

The persistence of aldrin and other organochlorine compounds has also been studied in sandy soils. Dissipation of aldrin residues is rapid in sandy soil under *bajra* cultivation than clay loam soil under maize cultivation. It has also been reported that even after 14 years, the concentration in soil retained about 40% of the dose applied in the beginning (Kushwaha et al. 1981).

Five varieties of Indian soils (alluvial, black cotton laterite, red and saline alkali) were treated with the nitrification inhibitors, 2-chloro-6-(trichloromethyl) pyridine (N-Serve) and 2-amino-4-chloro-6-methyl pyridine (AM) along with aldrin and dieldrin under aerobic and water-logged conditions. Under the former condition, the two inhibitors inhibited nitrification in alluvial, black cotton and red soils. N-Serve was effective only in the case of laterite soil while saline alkali soil was unaffected by the inhibitors. The insecticides did not affect nitrification. When the soil was water-logged, neither the nitrification inhibitors nor the insecticides showed any effect on the process (Narain & Datta 1974).

Organophosphorus pesticides persist in the soil for relatively short periods. The nature of the soil, however, plays a major role in determining the fate of this group of pesticides. During two consecutive *kharif* seasons of 1973 and 1974, three treatment dosages of 10, 20 and 30 kg parathion a.i./ha were applied thoroughly and uniformly in the soil up to a depth of 10–15 cm and soil samples were collected at 0, 5, 10, 15, 30, 60 and 90 days after treatment. Maize crop (*Zea mays*) was raised in the treated plots. Soil treatment dosages of 10, 20 and 30 kg a.i./ha had initial deposits of 2.628, 5.536 and 10.445 ppm in kharif 1973 while they were 2.506, 5.475 and 10.687 ppm in kharif 1974 respectively. The amount of the insecticide from the initial deposits left 3 months after the treatment was below detectable level at all the treatment dosages during both the years. The rate of degradation was faster in the early stage of treatment (Jat et al. 1981).

Organic matter, crop species and weather conditions play in significant part in modulating pesticide behaviour in the soil. The least persistent pesticides are those that are hydrolysed chemically even before soil micro-organisms get to work on them. In drought conditions, half the dimethoate in the top 3″ of treated soil disappeared in 4 days. The persistence of dimethoate studied in sandy loam and clay loam soils using unsexed *Drosophila melanogaster* indicated that half-lives of at 4.0 and 8.0 ppm doses in all the three types of soil were in the range of 5–7 days in 0.2″ and 5–14 days in 2–4″ layer. It took about 14–21 days to reach the level of about 30% of initial deposits in all the three soils. After 42 days, 1.25–15% of the initially applied insecticide was present in the two sampling layers of all the three soils. Leaching was more in sandy than in loam and clay-loam soils (Misra & Gupta 1972).

Because of its rapid degradation in various pathways, fenitrothion is generally not persistent in the environment. Dicrotophos persists in the soil up to 75 days. The process of degradation slowed down in the presence of fertilizers.

The carbamates are slightly to moderately persistent in the soil. Organic herbicides do not build up their residues for more than a year at the current level of usage on food crops. However, persistence is dependent on the chemical nature of the herbicide (Pandey & Agnihotri 1975).

4. Pesticide Residues in Cultivated Food Crops

Uptake of pesticides by plants depends, in general, upon the extent of contamination of soil by pesticides. Residues in the plant may increase with time, if the compound is persistent. Pesticides are absorbed by plants more readily from sandy soils than from soils rich in organic matter. Rain also plays an important role in dislodging and spreading pesticides in the soil soon after their application. Non-polar pesticides tend to be absorbed by the root surface whereas polar compounds readily pass through the plant epidermis and are translocated into the plant. Water solubility of the chemical affects absorption through roots and subsequent translocation. Soil nutrients play an important role in translocation following absorption.

Studies on pesticide residues in plants conducted in India vary from precise experimentation using radiolabelled compounds through supervised trials for effectivity under varying climatic and agricultural conditions to commodity monitoring where the treatment history is unknown. Residue levels of chlorinated hydrocarbons, organophosphates and carbamates have been determined on a variety of crops and vegetables in India and the extensive literature has been reviewed (Bindra & Kalra 1981; Agnihothrudu & Mithyanantha 1978; Dutta et al. 1975; ITRC 1978 and Agnihotri et al. 1980a).

4.1 Organochlorine Pesticides

γ-HCH (0.1%) when applied to Okra (fruit size 1-2″) resulted in an average deposit of 5.06 ppm. Three days after the treatment, the residue level came down to 3.26 ppm. A spell of rainfall caused a further significant reduction of the residues on the fruits. Fruits which developed from treated flowers showed translocation of HCH ranging from 0.55 to 1.60 ppm (Dewan et al. 1967). Sorghum (*Sorghum vulgare*) raised under the All-India Coordinated Sorghum Improvement Project at Hyderabad, Kanpur, and Udaipur and treated with HCH (10% granules) @ 3.75 kg a.i./ha in three applications showed at harvest HCH residues from 1.99 to 3.71 ppm. The residue was translocated to the grain (0.44 to 1.25 ppm) in the year of harvest and 0.55 to 1.55 ppm in the succeeding year (Kathpal et al. 1976b). Slightly higher values than those reported above were obtained in another study carried out on Sorghum crop at Delhi (Kathpal et al. 1976a). Initial residues of 10–11 ppm of γ-HCH on egg plant (*Solanun melongena*) fell below 10 ppm on the same day of the treatment. The half-life of γ-HCH on egg plant was shown to be 5 days (Jain & Gupta 1976). Furrow application of 5% HCH dust at the rate of 10 kg a.i. per ha to cowpea (*Vigna catjang*) and green gram (*Phaseolus aureus*) at sowing resulted in the accumulation of 16 ppm residues in the soil, of which 97.5% was lost within 100 days. The translocation was faster in cowpea than in green gram. At harvest, residue levels were 0.04 and 3.75 ppm in green gram and cowpea seeds respectively (Agnihotri et al. 1974b).

γ-HCH (0.1%) was applied to pea (*Pisum sativum*) twice—first during pod formation and then after a duration of 15 days. Residue in the seeds increased with time but decreased in the plants. At harvest, residue level in the seeds was 13.6 ppm while on the plants it was 2.41 ppm, 35 days after the second spray (Pande et al. 1977a).

In spinach (*Spinacea oleracea*) which was given two sprays of 0.1% HCH, maximum reduction of residues occurred during the first 3 days. Of the initial residues of HCH, 18.8% were left after 1 week. Washing the leaves with water reduced the residues by 60–75% (Jaglan & Chopra 1971).

Rapid dissipation of the residues of γ-HCH during the first 3 hours after application of 5 mg pesticide was noted on potatoes, cabbage, cauliflower and spinach. Dissipation was almost rapid in potato and cauliflower (Mukerjee et al. 1974). In a series of experiments conducted over a period of 3 years under two different soil and agroclimatic conditions at Udaipur and Jobner on carrot (*Daucus carota*), radish (*Raphanus sativus*) and beet (*Beta vulgaris*), it was observed that application of HCH in soil at 5, 15 and 30 kg a.i./ha before sowing resulted in a greater absorption of the pesticide by the crops grown on sandy loam soil than those grown on clay loam. Carrot absorbed the highest amount of HCH followed by radish and beet. In all cases, the pesticide concentration in the roots was below the tolerance limits, except for carrot grown on sandy loam soil with 30 kg HCH a.i./ha. It was concluded from the study that crops raised with application of normal doses were suitable for human and cattle consumption (Srivastava & Kavadia 1976, Yadav 1976 and Yadav et al. 1977a). The dissipation rate of HCH also appeared to be much faster in the tropical climate of India as compared to temperate climated (Kushwaha et al. 1980).

In the above study in clay loam soil at Udaipur, HCH was dissipated in 3 months to the extent of 77–83%, 84–90% and 84–90% when applied at rates of 5, 15 and 30 kg a.i./ha respectively while in sandy loam soil at Jobner, the dissipation of HCH was 65–74%, 75–80% and 76–81% at the respective treatments. There was no difference in the dissipation rates in *rabi* and *kharif* crops. Persistence of HCH residues was longer in light soils (18–20 months) than in heavy soils (15-16 months), although it was related to the type of crop grown (Yadav et al. 1980).

In the arid zone of Jodhpur, following soil application of HCH to chilli (*Capsicum annum*), 88% of the pesticide dissipated in 150 days (Pal & Kushwaha 1977). Maize (*Zea mays*) grown in a clay-loam soil and pearl millet (*Pennisetum typhoidenum*) in a sandy loam soil were treated with 5, 15 and 30 kg a.i./ha of HCH. At harvest, the residues in both the plants were well below detectable levels. Significant translocation of HCH was found only in 30 kg a.i./ha treatment dosage which was much below the tolerance level of 3 (Yadav et al. 1977b).

At Jobner and Udaipur, HCH dust applied to soil @ 5, 15 and 30 kg a.i /ha and mixed thoroughly in the upper 10–15 cm layer of soil before sowing of pearl millet and maize in season of 1972. The soil samples drawn at the time of sowing contained average pesticide deposits of 2.33, 7.28 and 14.20 ppm at Jobner and 3.53, 9.95 and 18.44 ppm at Udaipur corresponding to the above treatments. At the end of 4 month the average residues present at Jobner were 0.54, 1.23 ppm, whereas at Udaipur the residues were slightly lower, being 0.41, 1.01 and 1.89 ppm respectively (Kathpal et al. 1981).

Lindane was sprayed at 0.01 and 0.2% concentrations (1.1 and 2.2 kg a.i./ha) at curd formation of cauliflower using 1100 litre emulsion per ha. The initial residues of 10.86 and 16.82 ppm on leaves and 9.50 and 13.75 ppm on curds was recorded for the lower and higher doses respectively, which came down below detectable level after 21 days. Washing and cooking reduced the residues further up to 56.50 and 70.90% respectively depending on the age of residue and samples (Sarode & Lal 1981).

The absorption of aldrin and heptachlor by potatoes was studied under field conditions, following their application at the recommended dosages of 1.875 and 2.0 kg a.i./ha, respectively, at the time of sowing/earthing-up of the spring crop (Chawla et al. 1981). Analysis of potato tubers at harvest revealed that the combined residues of aldrin and dieldrin were slightly below the prescribed maximum residue limit of 0.2 ppm whereas those of heptachlor and its epoxide exceeded the limit of 0.05 ppm. The residues of aldrin and heptachlor in the soil were reduced by 89 and 67% respectively, during the period of growth (Chawla et al. 1981). Aldrin treatment before sowing of pearl millet @ 3, 9 and 15 kg a.i./ha gave residues which dissipated by about 89 to 93% in 3 months. After a lapse of 8.5 months, the corresponding residues ranged from below detectable level to 0.66 ppm showing thereby extensive dissipation of 92 to 100%. The amount of dieldrin residues which had possibly resulted from oxidation of aldrin during the experiment was 0.53, 0.85 and 2.11 ppm respectively in the above treatment dosages. The dissipation of aldrin and dieldrin together varied from 69 to 71% (Kathpal et al. 1981).

Residues of endrin were estimated in/on okra fruits sprayed with 0.025% endrin emulsion @ 1,000, 1,500 and 2,000 l/ha on 24, 34 and 46 days old plants respectively. The amount of residue was 0.07 ppm, 10 days after the second spray, and 0.03 ppm, 25 days after the third spray. The reduction in residues was faster during the first 7 days in case of both the sprays, and in this period approximately 91-93% of the initial deposit was dissipated.

Processing of potatoes eliminates the residues of septachlor by 60 to 70% and that of septachlor epoxide by 70 to 74% (Misra et al. 1977).

Three granular applications of endosulfan totalling 1.50 kg a.i./ha in sorghum whorls gave deposits in soil to the extent of 0.55 ppm which further reduced to 0.20 ppm in a period of 2 months (Kathpal et al. 1981). Black gram at the time of pod formation (50 days after sowing) was treated with endosulfan dust (4%), lindane dust (1.3%), phosalone (4.0%), and quinalphose (1.5%) respectively @ 100, 1, 3, 1.0 and 0.375 kg a.i./ha. The pod samples collected 1 and 7 days after the treatment respectively contained 23.56 and 3.86 ppm of endosulfan, 17.66 and 4.85 ppm of lindane, 28.15 and 2.10 ppm of phosalone and 25.30 and 3.71 ppm of quinalphos. The half-life of endosulfan was 3.3 days while that of lindane 6.1 days. Quinalphos and phosalone had half-lives of 1.85 and 1.80 days respectively (Rajukkannu & Balasubramaninan 1982). Okra was sprayed with 0.05% endosulfan during the fruit bearing stage @ 1000 l/ha. Endosulfan deposits on fruits averaged 0.41 ppm. Residues on the 3rd and 7th day samples were found to be 0.22 and 0.6 ppm respectively. The 10th day okra samples showed no detectable residues of endosulfan or its metabolites (Dikshit et al. 1975). The residues of endosulfan on leaves of 3 month old cauliflower crop from 0.05% treatment @ 1100 l/ha, reached below the tolerance limit of 2 ppm in 7 days from the first spraying and in 8 days from the second spraying carried out 20 days later. When the concentration of spray was 0.1%, time taken for dissipation was 10 days for both the sprayings. On curds the residues reached below the tolerance limit in 4 days for both the concentrations. A waiting period of 8 and 10 for the 0.05 and 0.1% concentrations was considered safe before the consumption of leaves (Verma & Lal 1976).

Residual levels of endosulfan were measured in tomato which had been sprayed with 0.05 and 1.0% solutions @ (1.67 and 3.33 kg a.i./ha respectively). The deposits after the first application ranged from 7.35 to 7.85 ppm and from 14.40 to 15.20 ppm after the second application. Ten days after the first application residues were 0.60–0.75 ppm in the lower concentration group and 0.40–0.80 ppm in the higher concentration group. Twenty-five days after the second spray, residues ranged from 0.80–0.20 ppm. Simple washing with water reduced the residues by 80%. Boiling of the tomato fruits caused a 90% reduction in the residue levels (Dikshit et al. 1980b). Endosulfan 35 EC at 0.05% and 0.1% was sprayed on *Zizyphus mauritiana* thrice at tri-weekly intervals. The deposits on fruits were 1.167 and 3.668 ppm for the respective dosages which after 14 days postspray was found to have completely dissipated. The waiting period observed, however, from the higher dosage was 2 days. Thorough washing of the fruits collected just after the third spray removed 57–78% of the residues, the residue level being below the prescribed tolerance limit of 2 ppm (Kushwaha & Pal 1980).

Grapevines were sprayed with endosulfan 35% EC at 500 ml/100 vine. Endosulfan residues were 11 ppm after 2 hr and 2 ppm after 1 day followed by a very slow rate of degradation thereafter. α-Endosulfan residues decreased faster than those of β-Endosulfan. A one day waiting period was sufficient for consumption, since the residue levels reached the tolerance limit of 2 ppm within that period (Singh & Chawla 1979). Endosulfan (0.04%) sprayed on maize @ 1000 l/ha resulted in a mean deposit of 20.23 ppm on maize leaves which dissipated by about 4.5, 73.5, 92.7, 99.9 and 100% in 1, 5, 15, 21 and 31 days respectively. The residues at 21 days were found to be 0.03 ppm and below detectable levels at 31 days. On cob husk, the residues were only 11.33 and 0.27 ppm, 1 and 3 days after spray and were below detectable levels in 7 days. No residues could be detected in the grains (Kavadia et al. 1977).

In another study on maize treated thrice with endosulfan 0.1% spray (2 kg a.i./ha) or twice with 4% granules (1.75 kg a.i./ha) in whorls, the insecticide dissipated faster when applied as a spray than as a granular formulation. The residues in both plant and cob husk 48 days after the last spray (harvest) were about 1.5 ppm, whereas 41 and 63 days after the second granular application (harvest), the residues were 0.8 and 1.72 ppm in the plant and 0.9 and 1.42 ppm in the cob husk respectively and were below the tolerance levels of 2 ppm (Kavadia et al. 1978).

The initial residues of endosulfan were 10.60 ppm from the 0.07% treatment and declined by 73.5% in 7 days, 90.5% in 15 days and 98.20% in 25 days. No detectable residues were found in seeds at harvest (Handa et al. 1980).

4.2 Organophosphate Pesticides

Initial deposits of malathion (0.05% sprayed on tomato were 4 to 6 ppm on the fruits. The loss of residue was 80% within 5 days and almost 100% within 7 to 9 days, the half-life of the residue being 3–4 days. Residues dissipated below 3 ppm within 3 days (Kavadia & Adarsh Shankar 1976). Malathion (0.2%) was sprayed over egg plant and tomato @ 2 kg a.i./ha at fortnightly intervals 1 week after planting. Samples of fruits collected between 24 and 144 hrs after spraying showed that the residue levels were below 8 ppm tolerance level prescribed by U.S. Food and Drug Administration. Lowest amount of malathion detected was 0.5 μg (Lakshminarayanan & Krishna Menon 1974).

In another study, malathion was used on tomato and pea pods both as spray and dust @ 462.1/ha and 22 kg/ha respectively. Deposits of malathion on tomato fruits and pea pods were found to be below the 8 ppm tolerance limit. Dissipation was more during March–April than during November-December. However, the residues were more on pea pods than on tomato fruits (Singh & Lal 1966).

Using the bioassay method, malathion residues were determined on egg plant fruits, when the insecticide was used at 0.01% concentration @ 350 l/ha. The deposits on the plants were between 17–18 ppm, which dissipitated below 8 ppm tolerance level within 3 days giving a half-life of 2–3 days (Jain & Gupta 1976).

Malathion (0.3%) was sprayed on cowpea @ 900 l/ha and the treatment was triplicated. The fruit samples collected at various intervals of time, showed that the residue levels after 24 hrs were 2.04 ppm which fell below detectable limits after 7 days (Dewan et al. 1969). In another study at 0.05 and 0.10% concentrations, the deposits on leaves were 31.20 to 33.80 ppm and 63.00 to 66.83 ppm respectively. On pods the residues were 18.0 and 32.50 ppm. There was quick dissipition of the residues and finally on residues could be found on leaves after 15 days and on fruits after 10 days (Fotedar et al. 1976).

Dissipation of malathion was very fast in the fruits of cucumber *(Cucumis sativus)* sprayed with 0.05% fenitrothion, fenithion, malathion and parathion-methyl. The half-life of malathion was found in this study to be 1.41 days (Hameed et al. 1980).

Following the application of malathion to okra plants @ 0.626 l a.i./ha, the fruits were collected at different time intervals and when analysed by GLC, 5.7 ppm of malathion were detected. 98.50% of the deposits dissipated within 5 days and were below the tolerance level of 5 ppm. By calorimetry, the residues could be detected up to 5 days. No residues were detected in the samples taken after 7 days of application (Deshmukh & Singh 1975). In another study, malathion at 0.05% concentrations was sprayed on the fruits of okra @ 100 l/ha. On the fruits, the average deposit was 2.12 ppm which dissipated to 0.5 ppm within 3 days. No residues could be detected on the 7th and 10th day (Dikshit et al. 1975). Malathion applied @ 250 g a.i./ha on 55 day old crop of okra resulted in a deposits of 0.22 ppm on the fruits picked at different time intervals after spraying. Dissipation was rapid (90%) within 2 days (Joia & Kalra 1974). Comparable results were obtained on application of the pesticide at concentrations between 0.05–0.1% (Jat & Srivastava 1973).

Malathion was applied to okra at concentrations of 0.05% and 0.1%. At these dose levels, washing removed 89 and 79% of the residues, open cooking removed 87 and 58%, steam cooking removed 76 and 58% while dehydration caused a reduction of 92 % the malathion residues. The fall in residue levels was much below the prescribed limit (Nath et al. 1975).

Malathion sprays on cauliflower could cause less than 30% mortality of the diamond black moth on the 11th day after spraying indicating its quick dissipation and hence low level of persistence (Yadava & Sachan 1975).

Malathion was used at three rates—375, 600 and 800 ml a.i./ha, on cauliflower grown in a sandy loam soil. Each treatment was triplicated. Four heads of cauliflower were picked at random at 0, 1, 5 and 7 days after spraying. Dissipation of the pesticide was found to be faster in spring than in winter crop, the half-life being 1.8 days in spring and 2.4 days in winter. Washing the heads brought about a further reduction in the residues (Gupta & Kapoor 1972). In another study, malathion 0.04% emulsion sprayed on cauliflower crop @ 121:45 l/ha dissipated below the 8 ppm tolerance level within 3 days and no residues could be detected 15 days after application (Yadava & Sachan 1973). Malathion at 0.1, 0.2 and 0.4% concentrations sprayed @ 1135 l/ha on cauliflower gave residues which dissipated up to 70% within 3 days, whereas after 7 days, 27–111 ppm of residues persisted. Washing the heads with water reduced the residues by 72–78 % (Sharma & Chopra 1970).

When 0.06% malathion was sprayed on cabbage @ 0.435 kg a.i./ha, the residues dissipated within the tolerance limit in 3 days on the heads and 7 days on the leaves, giving a half-life of 1.0 day on the heads and 1.63 days on the leaves (Sachan & Srivastava 1975). In another study, malathion was sprayed as 0.06% emulsion at the rate of 726 l/ha on cabbage. The residues on heads and leaves of cabbage fell well below the tolerance level (8 ppm) within 7 days in the case of leaves and within 1 day in the case of heads (Sachan & Srivastava 1973). A 0.08% emulsion of malathion when sprayed on cabbage could be detected up to 7 days. Washing removed the residue still further (Deshmukh & Bhalla 1973).

Comparative studies have been done on potato, cabbage, cauliflower, and spinach treated with 5 mg malathion. TLC analysis of the residue showed that although malathion dissipated most rapidly from potatoes and cauliflower, at least 5 days were required for the residues to dissipate below the tolerance level of 8 ppm (Mukherjee et al. 1974). Residues of malathion were estimated on cabbage, cauliflower and knol-khol (*Brassica olearacea*) after treating the crops with 600 and 1200 g a.i./ha in the form of EC, WDP and dust formulations using both chemical and bioassay methods. Deposits on cauliflower curds and outer portions of knol-khol were lower than that of foliage. Degradation was faster under high temperatures, low humidity and bright sunlight. In the winter crop, malathion in the form of EC, WDP and dust formulations took 12, 14 and 5 days respectively for the residues to dissipate below the 8 ppm tolerance level. In the spring season residue levels were higher than the tolerance limit up to 8 days. The half-life of residues was 1 to 3 in winter and 1 to 2 days in spring (Hameed & Lal 1971).

Malathion at 0.05%, 0.1% and 0.15% concentrations was sprayed @ 100 l/ha on the foliage and ears of wheet. One day after application, the deposits from 0.05 and 0.10% concentrations were 20.5 and 30.5 ppm respectively most of the residue dissipating in 2 days. However, when the dose applied was 0.15% concentration, the deposits detected were 53 ppm which persisted up to 10 days (Prasad & Saxena 1975).

Malathion was applied to the rice plant and the residues are determined on the leaves, harvested whole grains and dehusked grains. There was a gradual reduction of residues up to 15 days. Sun-drying and par boiling brought about a reduction in the residue level to nearly 90% but these levels were still above the tolerance limit of the pesticide fixed by EPA (Kannan & Jayaraman 1980). In another study, rice plants sprayed with 0.05–0.15% malathion, residues fell below the tolerance limit of 8 ppm within 3 days. Half-life of malathion was 1.3 days at 0.05% concentration 1.6 days at 0.1% concentration and 2.1 days at 0.15% concentration (Srivastava et al. 1975).

Malathion (0.05%) was sprayed on maize @ 100 l/ha. The resulting deposits from the spray were 25.13 ppm on maize leaves and 19.53 ppm on cob husk. The insecticide dissipated below tolerance level within 1 day and below detectable level within 3–5 days (Kavadia et al. 1977). In another study when malathion (50%) applied on maize grains at dosages of 30 and 40 ppm, residue levels came down to tolerance limits in 6–10 months. Seventy three percent of malathion dissipated during *Chapati* making (Bindra & Siddhu 1972). Malathion sprayed on barley at concentrations of 0.05, 0.1 and 0.15% @ 100 l/ha brought down the residues to levels below tolerance within 2–5 days (Singh & Saxena 1976).

Application of malathion @ 1.0 kg a.i./ha on sorghum left 1.21 ppm residue levels on the grains and 1.66 ppm on the stalks which were less than the tolerance limits prescribed by EPA (Rajukkannu et al. 1979).

Residue levels of malathion, diazinon, fenitrothion, methyl pasathion and phosalone on apples were determined following application @ 5 litres of 0.5% solution per tree. The residues ranged from below detectable limits to 1.0 ppm All residues were lower than the acceptable tolerance limits (Thakur & Hameed 1980).

Changes in the residue levels wese determined following field treatment of egg plant with 0.042% parathion solution @ 350 l/ha. The deposits were in the range of 20–21 ppm. Residues dropped below the tolerance limit of 1 ppm within 10 days after treatment giving a half-life on brinjal of 3–4 days (Jain & Gupta 1976).

Cauliflower was treated with parathion-methyl at two dosages, 0.325 and 0.52 kg a.i./ha. From the lower dose, a period of 4 days on cauliflower curds and 7 day. on cauliflower leaves were required for the dissipation of the pesticide to tolerance level whereas from the higher dose, the pesticide took 7 days from curds and 8 days to dissipate from the leaves to the tolerance limit (Attri & Lal 1974b).

An early crop (June to July) of cowpea was sprayed with parathion-methyl @ 0.35 and 0.56 kg a.i./ha. The residues in pods reached the tolerance limit of 0.7 ppm (FAO/WHO, 1971) in 1.0 and 2.2 days after treatment. On leaves it look 6–9 days for residues to fall to tolerance level. On the late crop (September to October) pods, the pesticide took 1.5–2.7 days to reach levels of tolerance (Attri & Lal 1974a).

In cauliflower, washing and cooking resulted in 40–65% loss of residues of parathion-methyl. However, in those cases where the residue level was more than 1.5 ppm, washing and cooking did not help in bringing it to tolerance level. In cowpea, however, washing and cooking decreased the residues by 65–70% bringing it down to safe levels (Attri & Lal 1974b). Parathion-methyl applied to black gram *(Phaseolus mungo)* and pea @ 0.625 and 1.25 kg a.i./ha resulted in residues which were below the tolerance level of 1.0 ppm 6 days after application (Singh & Singh 1978).

Egg plant was sprayed with parathion methyl @ 0.50 kg a.i./ha, 3 times in a randomized block design. Composite fruit samples collected just after application had deposits of 10.6 ppm while those collected at 1, 3, 5 and 7 days after application had 8.50, 6.50, 3.2 and 0.9 ppm of the pesticide respectively. However, after 10 days the residues on the fruits were below non-detectable limits (Rajukhannu et al. 1980).

Okra was sprayed with methyl parathion @ 0.50 kg a.i./ha 3 times in a randomized block design. On the day of application the residues of methyl parathion in/on the fruits were 10.50 ppm which came down to 0.60 ppm 7 days after application (Rajukhannu et al. 1978b).

Quinalphos spray resulted in the deposit of 1.8 ppm on tomato, which dissipated to the level of 1.2, 0.5 and 0.2 ppm in 1, 2 and 4 days representing 30, 72 and 88% degradation in 1, 2 and 4 days respectively. The results indicate that at least 3 days should elapse after spraying before marketing tomato fruits (Singh et al. 1980a).

Phosalone residues on tomato were initially 1.7 ppm while at the end of 1, 2 and 4 days after spraying they were 0.9, 0.7 and 0.4 ppm respectively. Phosalone residues in tomato reached below the prescribed maximum residue limit of 1 ppm in 1 day (Singh et al. 1980a).

Phosphamidon, desethylphosphamidon and γ-chlorophos-phamidon degrade rapidly on green leaves as compared to fruits. Potted plants of egg plant, chillies and peas in various stages of growth were simultaneously sprayed with 0.05% phosphamidon. The residues in foliage, periodically taken from crops of different stages (six leaf stage, commencement of flowering and fruiting stage) after the 0.05% spray were analysed. Higher deposits were noted when the plants were treated at six leaf stage. Within 12 days after spraying the residues in the fruits reached the FAO tolerance limit of 0.1 ppm (Shinde & Yadava 1981). While residues of diazinon were found in harvested paddy plants 50 days after application, soil contained no residues (Gupta 1974). There was quick degradation of chlorofenvinphos in soil and no residue was found in the potato tubers (Misra et al. 1977). Disulfoton degraded after 30 days of application in soil (Rajukkannu et al. 1973).

Grapes treated with fenthion four times at 15 day intervals, showed very low residues. A rapid degradation of the same was noticed in grapes, reaching to levels which were undetectable in 8 days (Rajukkannu et al. 1977b).

In cow-pea, pods treated with monocrotophos, the half-life period of the pesticide ranged between 2.7 and 3.1 days indicating its quick degradation (Awasthi et al. 1977b).

Phorate applied to puddled paddy soils degraded completely within 30 days (Rajukkannu et al. 1977a).

Tetrachlorvinphos, carbophenothion and trichlorofon were sprayed on Bengal gram at a concentration of 0.04–0.05%. The residues in the grains at harvest for carbophenothion, tetrachlorovinphos and trichlorofon were 3.5, 6.0 and 13.5 ppm respectively (Pandey et al. 1977b).

Dimethoate was applied to potato during the two crop seasons @ 300 and 500 g a.i./ha 5 times at 10 day intervals. From the residues of the two crop seasons (autumn and spring) it was observed that dimethoate residues persisted above the tolerance level upto 10 days following the last foliar spray treatment from both the dosages in autumn crop and only from the higher dose in spring crop, in unwashed and unpeeled potatoes. At harvest the residue was well below the tolerance limit of 2.0 ppm on/in unwashed and unpeeled potatoes. Washing and peeling of such potatoes brought down the level to a considerable extent. Dimethoate residue in washed and peeled potatoes was well within the tolerance limit even on first sampling which was done 10 days after the last spray treatment. No detectable quantity of dimethoate was found either in washed, boiled and peeled potatoes or from water in which potato samples collected from different experimental plots, were boiled for cooking, at any time from any of the dosages (Misra et al. 1981).

Persistence of dimethoate and methyl-demeton in and on pea pod shells and their movement into pea grains was studied during the Rabi season. The insecticides were applied @ 300 and 315 ml a.i./ha each time as foliar spray after 50% pod formation at 15 day intervals. After the last treatment the deposits were 12.72 and 13.04 ppm in pod shells and 20.68 and 13.50 ppm in grains respectively. Dimethoate residues reached below tolerance level within 10 days after the last spray while it took 21 days in case of methyl-demeton in both the substrates. The residues of both the insecticides were below detectable level when grain samples were analysed 30 days after harvest (51 days after last treatment). The half-life values were 5.1 and 3.7 days in case of pod shells and 1.6 and 3.4 days in grains for dimethoate and methyl-demeton respectively (Singh & Yadav 1981).

Experimental potato plots were treated with phorate granules, applied near the base of plants at first earth turning time: oxydemeton methyl, sprayed on plants at 150, 300 or 400 g a.i./ha at 10–12 day intervals; or aldicarb, 1.0 and 1.5 kg a.i./ha applied at first earth turning time of autumn and spring. Quantities of phorate residues were above the tolerance level of 0.5 ppm on or in unwashed and unpeeled as well as from unwashed and peeled potatoes at harvest. The concentration increased with time from the date of application to harvest. Oxydemetonmethyl residues were within the tolerance limit of 0.2 ppm after 2 or 3 days of the last foliar spray treatment. No detectable quantities of this chemical were found on processed potatoes. At normal harvest time, 70 days after aldicarb application to the soil, residues were within tolerance limits on or in unwashed unpeeled potatoes (Misra & Awasthi 1980).

Egg plant seedlings (35 days old) sprayed with pesticides showed the following order of persistence: dimethoate > endosulfan > phoxin > monocrotophos > quinalphos (Veeravel & Bhaskaran 1979).

Studied using 0.05% emulsion of fenitrothion @ of 1000 l/ha on cabbage revealed that the residues were more than the tolerance limit of 0.3 ppm up to 3 days on cabbage heart and 6 days on leaves when estimated by bioassay. But by colorimetry, the waiting periods were estimated to be 14.2 and 22 days respectively. Washing and cooking of the cabbage heart further degraded the residue and reduced the waiting period to 1.3 days. Similarly washing of leaves brought down the waiting period from 6 to 5 days (Attri 1977a).

Residues when applied to cauliflower as 0.05% emulsion of fenitrothion were more than the tolerence limit of 0.3 ppm up to 9.5 days on curds and 13.8 days on leaves when estimated by the bioassay method. However, by chemical assay, the waiting periods were found to be 1.48 and 16.0 days on curds and leaves respectively. Washing and cooking removed 24–60% residues depending on the sampling time and the amount of residue already present (Attri 1976, 1977b).

Okra was sprayed with fenitrothion @ 1.0 kg a.i./ha 3 times in a randomized block design. Initially the deposits on the fruits were 3.8 ppm which fell to a value of 0.5 ppm 7 days post-application (Rajukkannu et al. 1978b).

Fenitrothion was applied to okra 55-day old crop @ 150 g a.i./ha. The initial deposits on the fruits were 0.14 ppm of which 71% degraded after 1 day and the residue level after 2 days was reduced to 0.014 ppm (Joia & Kalra 1974).

After spraying cucumber vines with 0.05% fenitrothion, the fruits were sampled immediately after drying and also at 1, 3, 5, 7 and 15 days. Residue determinations in field samples showed that the half-life of the pesticide was 2 days. A safety interval of 9 days for fenitrothion on the fruits of cucumber is presumably required before consumption (Hameed et al. 1980).

Fenitrothion was used as spray on egg plants @ 1.0 kg a.i./ha and the treatment was replicated thrice in a randomized block design. Composite fruits samples were collected at 1 hr, 1, 3, 5, 7 and 10 days after the last spray and analysed for residue both by bioassay and chemical assay methods. The initial deposit on the fruits was 2.6 ppm which fell to 0.40 ppm after 5 days and were not detectable after 7 days. Hence a waiting period 3.3 days on the fruits is suggested before consumption (Rajukkannu et al. 1980).

Fenitrothion was applied to the rice plant *(Oryza sativa)* and the residues were determined on the leaves, harvested whole grains and dehusked grains. There was a gradual reduction of residues in these portions up to 15 days. Sun drying and par boiling brought about a reduction in the residue levels by nearly 90% but these levels were still above the tolerance limit fixed by EPA (Kanan & Jayaraman 1980).

Fenitrothion was applied to maize either as furrow treatment or seed dressing @ 1 g/ a.i. metre now. Residues from soil samples from 0 to 15 cm layer collected at 0, 55, 81 and 172 days after application and the residues extracted from the grains at harvest were assayed for toxicity to Drosophila. At 81 days fenitrothion was not detectable in the soil. When fenitrothion was applied as a seed dressing, the residues in harvested maize were also below tolerance limits. However after furrow application the pesticide in the harvested maize was above thet olerance level (Kakkar et al. 1980).

Fenitrothion was sprayed on maize @ 1.075 kg a.i./ha. At harvest 0.084 ppm of the residue was present in the grains which degraded further to a level of 0.1 ppm at 21 days. The fodder contained 0.2 ppm at harvest. Boiling and roasting brought down the residue level to a still lower level (Deshmukh & Joia 1973).

In an experimental trial, phorate was applied to the soil @ 1.5 kg a.i./ha before sowing of green gram and red gram. Initial deposits of phorate in the soil varied between 7.5 ppm and 9.4 ppm under laboratory conditions as compared to 39.5 ppm and 11.5 ppm in the soil under field conditions. Green gram and red gram were grown in soil both in the laboratory and in the field. Both these soils were then treated with phorate. The residues of phorate in the leaves of green gram and red gram under laboratory conditions, 23 days after application were 3.90 and 7.93 ppm. The residues came below detectable levels in 150.8 in green gram and 77.8 days in red gram. While under field conditions, for the same time period after application, the residues were 4.9 and 65.4 ppm in the leaves of green gram and red gram respectively, it look 49.2 in the case of green gram and 62.1 days in the case of red gram for the residues to dissipate below the detectable level.

The uptake of phorate from the soil by plants and its degradation in soil and in plants was generally less under laboratory than when studied under field conditions (Verma & Pant 1979).

Granules of 10% phorate and 5% disulfoton were broadcast @ 1.5 kg a.i./ha after 7 days of transplantation of paddy in the wet field. At the time of ear-head formation, the plants were sprayed with emulsion of one of the following insecticides: 0.1% malathion 0.05% fenitrothion, 0.05% chloropyrifos, 0.075% endosulfan and 0.1% lindane @ 500 l/ha. In addition, HCH 5% dust was also applied @ 5 kg a.i./ha. The deposits of disulfoton and phorate were 6.0 and 5.8 ppm respectively and the residues persisted for 60 days. The degradation was linear and rapid during the first 30 days of application. 75% disulfoton and 78.4% phorate was lost, and thereafter, degradation progressively declined. The soil water collected after 10 days of application contained 10 μg and 2 μg on 20th day and undetectable levels on 30th day. The levels of the insecticides in the plant were found to increase till 30th day of application: 1.55 ppm phorate and 1.75 ppm disulfoton, thereafter the residues gradually declined. All the three organophosphorus insecticides were rapidly dissipated and no detectable residues were found after 22 days of application. The residues of endosulfan and HCH persisted for 22 days, but there were no residues on the 30th day after harvest. Lindane residues however, persisted in grains till harvest although the levels were lower (0.15 ppm) than the tolerance limit of 0.25 ppm prescribed by FAO/WHO for foodgrains (Jain et al. 1980).

Dissipation of monocrotophos from chick pea *(Cicer arietinum)* sprayed at the pod formation stage at concentrations of 0.04, 0.06, 0.08 and 0.1% was studied. Samples were taken at 0, 1, 3, 7, 10, 20 and 44 days after treatment. The deposits from 0.04, 0.06, 0.08 and 0.1% concentrations on chicken pea plants were 9.42, 14.53, 18.59 and 21.94 ppm respectively. The rate of dissipation was rapid in the beginning. On the 10th day after application, the percentage reduction in the residues showed values of 91.30, 86.40, 83.30 and 80.72. The maximum time required for the residues to reach the 0.5 ppm tolerance limit was 10.31, 19.00 19.88 and 25.26 days for the four concentrations (Singh & Gupta 1981).

Deposits of monocrotophos on okra fruits ranged from 0.23 ppm to 0.49 ppm in different experiments. A 4 day gap between spraying and harvesting was found safe for consuming okra. For days 0, 1 and 3 post-spraying the percentage reduction of monocrotophos residues due to washing was 61, 50 and 25 respectively (Krishnaiah & Prasad 1978). Monocrotophos at 0.03 and 0.05% concentrations was sprayed

@ 1100 l/ha on okra at the fruit-bearing stage. Each treatment was replicated 3 times. A repeat application was done 20 days after the first spray. Samples after the spray treatment were collected after 1 hour and then after 3, 7, 10 and 15 days. The deposits from the 0.03 and 0.05% concentrations were 2,80 and 6.25 ppm after the first spray. The percentage reduction of these residues was 36.8 and 37.6 in 3 days 71.0 and 63.2 in 7 days and 81.5 and 82.4 in 10 days. Further, no detectable residues of monocrotophos could be found from the 0.03% spray treatment after 15 days. After the second spray, the deposits from the 0.03 and 0.05% concentrations were 4.2 and 7.0 ppm. They were reduced to 2.42 and 4.30 ppm in 3 days, 0.80 and 1.30 ppm in 10 days and below detectable limits and 0.08 ppm in 15 days (Dikshit et al. 1981). Two hours after spraying of monocrotophos, the residues on chilli leaves and fruits were 88.79 and 11.97 ppm with a further dissipation at 120 hours post-spraying, the respective residues on leaves and fruits were 9.58 and 0.76 ppm. The rate of dissipation was more from the fruit than from the leaves (Narkhede et al. 1977).

Phosalone was sprayed at 0.05 and 0.10% concentrations on black gram at 12 day intervals under irrigated under unirrigated conditions. Leaf samples were collected at 0, 1, 4, 8 and 12 days after spraying and residues analysed revealed that half-life values ranged from 3.02 to 3.29 and 3.44 to 4.46 days under irrigated and unirrigated conditions respectively. For the residues to fall below the tolerance limit of 1 ppm, spray of 0.05% phosalone took 10.96 and 11.12 days while the second spray with 0.10% took 15.03 and 16.34 days under irrigated and unirrigated conditions respectively (Anand & Murthy 1982). Phosalone was applied both as dust (0.60 kg a.i./ha) and as a spray (0.44 kg a.i./ha), three times to sorghum and showing. Composite grain and stalk samples collected at harvest had no detectable residues in the grains. However, the stalk had residues of 0.45 and 0.36 ppm from the dust and spray applications respectively (Rajukkannu et al. 1979).

Egg plant was sprayed with phosalone at the rate of 0.70 kg a.i./ha, three times in a randomized block design. Composite fruit samples collected just after application had deposits of 4.0 ppm while those collected at 1 and 3 days after application had 2.40 and 1.40 ppm of the pesticide respectively. For the time periods, 5, 7 and 10 days, the respective residues on the fruits were below non-detectable limits (Rajukkannu et al. 1980). Phosalone (0.6%) sprayed on tomato at the rate of 0.437 kg a.i./ ha showed a mean deposit of 1.7 ppm on the fruits. The residues at the end of 1, 2 and 4 days were 0.09, 0.7 and 0.04 ppm respectively. The residues in tomato reached values below the prescribed maximum residue limit of 1 ppm in 1 day (Singh et al. 1980a).

Chilli and Okara were sprayed separately with 0.05 and 0.1% concentrations of phosalone. The samples of chilli fruits from the 0.05% treatment showed deposits of 9.4 ppm from the last spray which came down to non-detectable levels within 10 days. The half-life of the residue was 1.4 days. In case of treatment with 0.1% concentration the deposits were 19.3 ppm which dissipated by more than 98% within a period of 10 days. The deposits of phosalone on okra fruits were 9.4 ppm from the 0.05% spray, which dissipated by more than 97% within a period of 7 days. The half-life was 1.3 days. The fruits from the treatment with 0.1% spray showed deposits of 17.10 ppm which dissipated by 98% within a period of 8 days (Pokharkar & Dethe 1981).

In field experiments. sweet potato *(Ipomoea batata)* was treated five times each with phosalone 0.525 kg a.i./ha fenthion (0.75 kg a.i./ha), manocrotophos (0.300 kg a.i./ha), endosulfan (0.79 kg a.i./ha), quinalphos (0.375 kg a.i./ha) and only once with carbofuran (1.0 kg a.i./ha) in a random block design. Bioassay and chemical assay for insecticide residues were performed on tuber samples at the time of harvest. Pesticide residues in tuber samples were found to be well below the recommended tolerance limits. It is suggested that among the aforesaid pesticides only carbofuran and aldicarb application should be restricted to a dose of 1.0 kg a.i./ha, as they may cause 1.0 kg a.i./ha residue hazards above (Rajukkannu et al. 1978).

Experiments were carried out to determine the decline of phosalone and quinalphos residues on tomato under north Indian climatic conditions. In field studies, tomato plants were sprayed with quinalphos and phosalone @ 0.250 and 0.437 kg a.i./ha respectively. Marketable tomatoes were removed at 0, 1, 2 and 4 days after spraying. Residues were extracted and analysed by gas chromatography. Quinalphos spray resulted in deposit of 1.8 ppm on tomatoes, which was reduced to 1.2, 0.5 and 0.2 ppm on days 1, 2 and 4 respectively. Phosalone residues were 1.7 ppm initially, and dissipated to 0.9, 0.7 and 0.4 ppm after 1, 2 and 4 days respectively. Phosalone residues were below the prescribed maximum residues limit of 1 ppm of day first. It is suggested that there should be a gap of 3 days between spraying and marketing of tomatoes sprayed with quinalphos (Singh et al. 1980a).

Chemical assay and bioassay of fenthion (0.75 kg a.i./ha), phosalone (0.525 kg a.i./ha), monocrotophos (0.30 kg a.i./ha), endosulfan (0.79 kg a.i./ha) quinalphos (0.375 kg a.i./ha), carbofuran (1.0 kg a.i./ha), aldicarb (1.0 kg a.i./ha) and disulfoton (1.00 kg a.i./ha) sprayed on sweet potato tubers revealed insignificant residue in the tubers all below the accepted tolerance levels.

Quinalphos was applied to the main and spring crops of cauliflower @ 250 g a.i./ha in field tests designed to study its dissipation. Spring crop showed residues of $<$ 0.25 ppm after 4 days while the main crop samples took 7 days to reach this residue level. After 8 days, approximately 95% of the applied dose had dissipitated from cauliflower heads (Chawla et al. 1979a).

Quinalphos (0.03%) sprayed on tomato crop at the rate of 0.250 kg a.i./ha resulted in an initial deposit of 1.8 ppm on the fruits, which dissipated to the level of 1.2, 0.5 and 0.2 ppm in 1, 2 and 4 days respectively. The percentage reduction in quinalphos residues was 3 0, 72 and 88 in 1, 2 and 4 days respectively (Singh et al. 1980a).

Egg plant was sprayed with quinalphos @ 0.50 kg a.i./ha, three times in a randomized block design. Composite fruit samples collected just after application had deposits of 4.70 ppm while those collected at 1, 3 and 5 days after application had 4, 10, 2.50 and 1.10 ppm of the pesticide respectively. For the time periods 7 and 10 days the respective residues on the fruits were below detectable limits (Rajukkannu et al. 1980).

Quinalphos @ 0.50 kg a.i./ha was applied three times to sorghum after sowing. Composite grain and stalk samples collected at harvest showed 0.32 and 0.85 ppm of the pesticide respectively. The level of residues at harvest was well below the tolerance limit of 2.0 ppm (Rajukkannu et al. 1979).

An insecticidal schedule involving application of 1.0 kg a.i./ha mephosfolon to 15–20 day old maize plants was evaluated for residues. The initial deposit in the 0–25 cm soil was 18.09 ppm. The residues gradually declined with time and no detectable residues could be found on the 60th day. The rate of dissipation was faster up to 21 days after which it was slow. The half-life calculated was 9.7 days for the first 21 days and 12 days for the remaining period. Three days after the application, the leaves contained 4.93 ppm of the insecticide. The concentration in leaves further increased to 7.92 ppm on the 7th day, but thereafter it gradually decreased with time and reached almost to non-detectable levels (0.50 ppm) on the 60th day. The residues in stem were maximum on the 3rd day and decreased gradually to non-detectable levels on the 60th day. No detectable residues were found in green cobes, grain or straw samples at harvest (Sahu & Agnihotri 1980).

4.3 Carbamates

Three days after spraying 2000 ppm of thiram on the leaves of Eureka lemon plants, 550 ppm were present on the leaves. This amount was reduced to 100 ppm at 15 days indicating that the fungicide persisted on the leaves even 15 days post-spraying (Beniwal & Chaubey 1976).

Residues of carbofuran in unirrigated plots after 15 days of application were 5.04 ppm, and came down to 0.60 ppm after 75 days of application. The corresponding values in irrigated plots after 45 days of application were 1.80 ppm while after 60 days of application, the residues came down to 0.60 ppm. However, no detectable residues were found in the soil after 75 days in irrigated plots.

Investigations on the dissipation of aldicarb in soil and pea plants reavealed that the initial residues of aldicarb in the soil wad 13.70 ppm and its degradation followed first order kinetics with a half-life of 17 days (Dikshit et al. 1976). In pea, the residues, persisted for 110 days and were concentrated in the top portions of the plant.

Aldicarb was applied in granular form at rates of 2.0, 3.0 and 4.0 kg al/ha in 1976-77 and @ 1.0, 2.0, 3.0, 4.0 and 5.0 kg a.i./ha in 1977-78 at planting time. The residues were 0.55, 0.90 and 1.20 ppm in raw tubers of potatoes following the 2, 3 and 4 kg a.i./ha treatments. In tuber stored for 1 month residues were reduced by 62.5–100% which were well below the limits set by EPA. Peeling raw potatoes caused a 63.65% loss of residues. Boiling, followed by peeling removed 94–100% of the residues. Residues at harvest ranged from 0.45 to 1.82 ppm when treated at 1.0–5.0 kg a.i./ha. The dissipation rates followed the same trend in the reduction of residues as noted earlier. Tubers stored for 60 days had no detectable residues. The majority of aldicarb residues were detected in the potato skins (Awasthi et al. 1979).

Disulfoton, aldicarb and fensulfothion were applied @ 1.00 kg a.i./ha to the grains of cowpea, black gram and green gram. The result showed that fensulfothion had left residues (0.15–0.46 ppm) both in the tender pods and mature grains of cowpea. In black and green gram also the residues were above the tolerance level (0.22–0.31 ppm). Aldicarb and disulfoton left residues which were well below the tolerance levels prescribed by Food and Drug Administration of USA in all the three pulses (Rajukkannu et al. 1977c).

Two applications of 0.1 % and 0.2 % at fortnightly in intervals and dipping the berries of grape (*Vitis vinifera*) in 2,000 ppm of carbaryl suspensions were conducted in the field. In all the experiments the initial deposits of carbaryl varying from 63 to 133 ppm dissipated fairly rapidly. Washing the treated grapes for 30 seconds removed 49 to 85 % of the residues, depending upon the time lapse after the treatment (Kathpal et al. 1978).

Okra was treated with 0.25 % carbaryl spray @ 360 litres per acre at fruit-learning stage. The treated fruits of size 1″ on the 4th day were found to have no residues. However, on the fruits of size 1–2″ the average deposit was 1.5 ppm which gradually declined. Three days after the treatment, there were no residues. A spell of rainfall significantly reduced the insecticidal contamination of the fruits (Dewan, et al. 1967). In another study okra was sprayed with carbaryl four times @ 25 kg a.i./ha. Residue levels of 4.60 ppm were present on the fruits 1 day after the second spraying, which was reduced by 96.3 % after 7 days. Initial deposits on okra fruits after third and fourth spraying were 7.0 and 6.4 ppm while the values for one-day old residues wese 3.1, 143 and 3.7 ppm (42.4 %) respectively. Initial deposits were degraded by 98.3 and 98.1 % after 7 days and no residue was detected in samples thereafter (Deshmukh & Singh 1975).

Carbaryl (0.2 %) sprayed on maize @ 100 1/ha resulted in an average deposit of 27.6 ppm on leaves which degraded by 18.1 % in 1 day, 30.4 % in 5 days and > 90 % in 11 days. The residues found 21 days after application were 0.13 ppm, and below datectable level at 31 days. In case of cob husk, the carbaryl deposit of 21.3 ppm was reduced to the extent of 41.6, 70.9, 85.6, 99.7 and 100.0 % in 1, 3, 5, 7 and 11 days respectively. The residues in grain at all the intervals were found to be below detectable level. The half-life value of carbaryl on leaves was 3.91 days and on cob husk 1.83 days (Kavadia et al. 1977).

Bengal gram crop was treated with carbaryl @ 2.50 and 3.75 kg a.i./ha twice at an interval of 12 days, starting at the pod formation stage. The samples of gram foliage and grains (green) were drawn just before the second application and at intervals of 0, 1, 3, 7 and 15 days after the second application. The gram grain (dry) and straw samples were drawn at harvest. The carbaryl deposits in/on gram foliage varied from 51 to 52.4 ppm, which was less than the tolerance limit of 100 ppm fixed by FAO/WHO for cattlefeed. The residues in grains (green and dry) were far below their respective tolerance limits prescribed by FAO/WHO (Singh et al. 1980b).

Carbaryl (4 % granules) applied to plots of sandy loam soil @ 20, 40 and 60 kg a.i./ha revealed that much of it was lost within 15–30 days. In 90 days, the reduction reached 94–100 %. At all stages of growth bajra crop, there was no detectable residues of carbaryl (Gangwar et al. 1979).

A particular variety of rice was treated with sevidol (A granular insecticide containing carbaryl, lindane and other isomers of HCH) @ 1.0 and 1.5 kg a.i./ha at 30 and 58 days after transplanting. All treatments were replicated thrice in a randomised block design. Samples of whole grain, straw and soil were analysed separately. The carbaryl residues in or on whole grain harvested after 15 to 34 days after last application varied from below detectable levels (BDL) to 0.79 ppm which was lower than the Indian tolerance limit of 1.5 ppm on food grains and 5.00 ppm prescribed by FAO/WHO on rice. Whole grain samples showed non-detectable residues at application @ 1.0 kg a.i./ha but at a higher rate (1.5 kg a.i./ha) residues were more varying from BDL to 0.79 ppm. Carbaryl residues in and on straw varied from BDL to 4.38 ppm which was far below the tolerance limit of 100 ppm prescribed for fodder.

Lindane residues in whole grain varied from BDL to 0.23 ppm which were below to Indian tolerance limit of 0.25 ppm on grains and FAO/WHO tolerance limit of 0.50 ppm. Whole grains treated with higher dose of 1.5 kg a.i./ha showed slightly higher residues than those treated at 1.0 kg a.i./ha. Straw samples showed residues of 0.10 to 0.41 ppm. Lindane residues in soil varied from 0.11 to 0.51 ppm. Lindane persisted in soil < carbaryl (Singh et al. 1981).

Forty-day old maize crop was sprayed with 0.2% zineb. On day 1, 3, 5 and 10, and leaf surface and residues of 100, 50, 15 and 10 ppm respectively. On day 15 and 25, the residues on the leaf surface were below detectable levels. In leaf tissue, the respective residues for day 1 and 3 were 10 and 5 ppm respectively. The residues reached below detectable limits on days 5, 10, 15 and 25 (Annapurna & Rao 1982).

Forty-day old plants of Bengal gram were sprayed with 0.2% dithane Z-78. On day 2 and 5 the leaf surface had residues of 100 and 25 ppm respectively. On day 13, 27 and 40 the residues on the leaf surface were below detectable levels. In leaf tissue, the respective residues on day 2, 5, 13 and 27 were 160, 80, 20 and 8 ppm. On day 40, the leaf tissue had residues which were below detectable limits (Annapurna & Rao 1980).

4.4 Fungicides

Forty-day old plants of Bengal gram were sprayed with 0.2% captan. On day 2, 5, 13 and 27, the leaf surface had residues of 800, 600, 450 and 150 ppm respectively. On day 40, the residues on the leaf surface were below detectable levels. When the leaf tissue was analysed, the respective residues on day 2, 5 and 13 were 50, 25 and 10 ppm. On day 27 and 40, the leaf tissue had residues which were below detectable levels (Annapurna & Rao 1980). Five per cent dust of heptachlor was mixed in the top 15 cm soil @ 10 kg a.i./ha. There was an initial residue.

Forty-day old plants of *Zea mays* were sprayed with 0.2% captan. On day 1, 3, 5, and 15 the leaf surface had residues of 425, 450, 400, 385 and 110 ppm respectively. On day 25 the residues on the leaf surface were below detectable levels. When the leaf tissue was analyzed, the respective residues on day 1, 3, 5 and 10 were 18, 10, 11 and 2 ppm. On day 15 and 25 the leaf tissue had residues which were below detectable levels (Annapurna & Rao 1982).

4.5 Weedicides

As in a case of fungicides, work done in India on residues of herbicides on crops, vegetables and fruits is meagre. Fifteen days after sowing, groundnut crop was sprayed with 2, 4-D @ 0.6, 1.2, 1.8, 2.4 and 3.6 kg/ha. Residues levels on the leaves were determined using samples taken at 15, 45 and 75 days after spraying. The residues of 2, 4-D increased with increasing application dose and the same was not detected after 75 days on the leaves of plants sprayed with 0.6 and 1.2 kg/ha (Chopra et al. 1973) of 3.4 ppm which was rapidly lost in 180 days, the percentage of residue lost being 86.4 (Agnihotri et al. 1977).

4.6 Synthetic Pyrethorids

Okra was treated with cypermethrin @ 40 g/ha fenvalerate @500 g/ha cypermethrin @ 60 g/ha, permethrin @ 400 g/ha, malathion @ 500 g/ha and on untreated check. The experiment was carried out in a randomised block design with six treatments and three replicates. The insecticides were sprayed twice, first just after the appearance of pest and the second after 15 days. The initial deposits of fenalerate, permethrin and malathion on okra fruits were 4.7, 4.4 and 4.2 ppm respectively. The rate of dissipation of both fenvalerate and permethrin was lower than that of malathion. The loss of malathion on 1st, 3rd and 7th day was 66.6, 85.7 and 100.00% respectively. The relative loss of fenvalerate was 46.8, 74.5 and 87.2% while for permethrin it was 50.0, 72.3 and 88.6%. The initial deposits of cypermethrin were low (1.10 and 1.3 ppm only) as compared to fenvalerate or permethrin because of the low rates of application. The rate of loss of cypermethrin was 5.4–12.5% lower than fenvalerate and permethrin. Cooking removed 50–60% fenvalerate, 70–80% permethrin and cypermethrin and 90–98% malathion bringing the residues, well below the tolerance limit of 0.5 ppm suggested for permethrin and cypermethrin (Rao et al. 1980).

The insecticides permethrin (0.017%), cypermethrin (0.015%) decamethrin (0.00375%), fenvalerate (0.0067%), DDVP (0.05%) carbaryl (0.05%) were sprayed on cabbage @ 375 l/ha. The initial deposits of permethrin, cypermethrin, fenvalerate and decamethrion were 5.11, 4.80, 2.30 and 1.45 ppm respectively. The residues persisted for 5 days in decamethrin treated plots whereas in other treatments, the residues were present on the 10th day also when the last sampling was done. The plant contained 0.20 ppm fenvalerate, 0.35 ppm cypermethrin and 0.86 ppm permethrin. The rate of dissipation was highest for decamethrin followed by cypermethrin, fenvalerate and permethrin. The initial deposits of carbaryl, DDVP and endosulfan were 9.4, 14.00 and 16.75 ppm respectively. On the 10th day plants contained 0.66 ppm, DDVP, 0.75 ppm carbaryl and 1.50 ppm endosulfan (Agnihotri et al. 1980). Different vegetable viz. cauliflower, okra, spinach and tomatoes were separately sprayed with fenvalerate 0.05% EC @ 500 1/ha in the field. The initial deposits in cauliflower head, okra, tomatoes and spinach were 0.86, 4.0, 0.85 and 9.5 ppm respectively. The residues in cauliflower and okra persisted for 15 days and in spinach and tomatoes, for 30 days washing with cold water was only effective on the initial day of application, removing about 30–50% of the residues. Cooking removed about 30–50% of the residues. Cooking removed 71–88% residues on the initial day but later analysis revealed that its removal was 68–70% is spinach and tomatoes, and 38–40% in okra and cauliflower (Jain et al. 1979).

5.2 Organophosphate Pesticides

Malathion emulsion (0.0625%) was sprayed on mustard @ 1.685 l/ha and 2.021 l/ha at an interval of 23–24 days. Residues as determined by both bioassay using *Drosophila melanogaster* and chemical assay reached below the tolerance limit of 8 ppm even earlier than 3 days in case of leaves and 4 days in case of green pods and flowers. No residue could be detected in seeds (Kavadia & Lal 1968). Following ultra-low volume aerial application of malathion for mosquito control, the residues on the grass were 315 ppm and were thus much above the permissible limits. Within 4 days the residue dissipated to a level which was within the tolerance limit prescribed for malathion (Gupta et al. 1980b).

Phorate (10%) granules at two different doses i.e., at 2.3 kg a.i./ha and 5.0 kg a.i./ha were applied 3 times in randomised blocks, to mustard. The residues in unwashed leaves and stems in plants aged 15 days from the 2.3 kg a.i./ha dose averaged 8.77 ppm, and then progressively increased to a maximum of 11.47 ppm on 50th day. The residues detected at four consecutive 10 day intervals were 7.3, 3.96, 2.58 and 1.15 ppm. No detectable phorate residues were found in 100th and 110th day samples. A similar trend was observed after application with the 5.0 kg a.i./ha dose. The phorate residues in the 15 day old samples were 13.40 ppm and by the 50th day the residues had risen to a maximum of 15.83 ppm. No detectable residues of phorate could be found in leaves and stems at harvest. Washing of 15, 25, 40, 50 and 60 day old samples of leaves and stems from both the treatments resulted in nearly 50, 70, 80, 90 and 95% reduction of phorate residues respectively (Dikshit et al. 1974).

Mustard was treated with 0.03 and 0.05% concentrations of metasytox. The deposits on plants from the above concentrations were 4.0 and 6.0 ppm. The deposits fell to 0.35 and 0.5 ppm in 10 days, and to 0.07 and 0.15 ppm in 15 days from the respective concentrations. Washing and boiling with water brought about a further reduction in the residues upto 92%. In some cases the pesticide levels were still higher than the 0.2 ppm allowable concentration. No pesticide was detected in the seeds at harvest (Dikshit et al. 1980a).

Metasystox 0.025% and monocrotophos 0.025% were sprayed on soybean crop at the flowering stage, and the spraying was repeated 20 days later. Plant samples from each treatment and replicate were drawn at 0, 3, 7, 10 and 15 days after the first application. Pod samples were collected at 0, 3, 7, 10, 15 and 20 days after the second application and soybean seeds at harvest. The deposits on leaves from both metasystox and monocrotophos (0.025%) after the first application ranged from 3.20 to 3.80 ppm (average 3.50 ppm), and 2.45 to 2.75 ppm (average 2.65 ppm) respectively. Metasystox residues persisted on the leaves to the extent of 0.05 ppm while monocrotophos residues were below detectable limits on das 15 of application. Aftert he second application of both metasystox and monocrotophos (0.025%) at the pod formation stage, the initial deposits were 3.3 and 2.50 ppm respectively. Further, the rate of dissipation of both the insecticides from pods after the second spray followed a trend similar to that seen after the first spray on leaves. Soybean pod samples with 0 day residues of 3.3 ppm metasystox and 2.5 ppm monocrotophos were subjected to washing and boiling. Simple washing with water resulted in 92 and 82% reduction in the residues of metasystox and monocrotophos respectively. The corresponding reductions from boiling of the beans were 90 and 95%. Even after washing and boiling the 0 day residues in all the cases did not fall below the tolerance limits of 0.2 ppm for metasystox and 0.05 ppm for monocrotophos as laid down by the FAO (Awasthi et al. 1978).

Monocrotophos was applied to plots in which sugar cane crop had been raised. There was quick degradation of the pesticide in the soil and no residues could be found in the sugar cane juice isolated from the treated crop (Awasthi et al. 1977a).

Dimethoate (0.03% spray) degraded quickly and no residue was seen 48 hrs after treatment of tobacco plants, suggesting the safety of this insecticide in tobacco cultivation (Joshi & Ramprasad 1969). Dimethoate was not detected on fruits like peach and guava; approximately 50% of the initial deposit was degraded within 3–5 days (Sohi 1974).

Cotton plants were grown in plots and then treated 6 times at fortnightly intervals with a 50% EC of fenitrothion @ 425 ml a.i. per acre, 15 days after it had been sprayed with DDT and HCH mixture (50% WP) @ 0.250 kg a.i./ha. The residues on cotton seed and lint were 0.06 and 0.27 ppm respectively (Chawla & Kakkar 1981).

Tobacco plants were grown in plots that received 1.5 kg a.i./ha and 1.0 kg a.i./ha each of phorate, disulfoton and aldicarb. One hundred and 5 days after application, residues in leaves were 0.160 and 0.135 ppm from the 1.5 and 1.0 kg a.i./ha doses respectively, while from the same dosages the respective residues for disulfoton and aldicarb (expressed as aldicarb sulfoxide) were 0.340 and 0.265 ppm, and 0.110 and 0.085 ppm. The residue levels in all these cases were less than the tolerance limits (Natarajan & Subramaniam 1977).

After aerial application of monocrotophos to grass and cotton, the insecticide was found to have degraded by about 90% in the former and by 85% in the letter in 7 days (Rao et al. 1980).

Fumigation in excess dose may result in the loss of some vitamins particularly niacin and thimine from coffee (Muthu et al. 1973).

Five sprays of malathion were given to mustard. The first spray was done at a dosage of 0.31 kg a.i./ha. The subsequent sprays were done at 10 day intervals at dosages of 0.37, 0.44, 0.5 and 0.5 kg a.i./ha. After the first spray, the initial deposit of malathion was 7.15 ppm. Residue levels dropped after the third spray. Degradation of the insecticide was by 99.7 and 98.0% from the first and third sprays on day 50th. By day 9, no residues could be detected. However, the toxic metabolite, malaoxon could be detected in traces (Kalra & Kalra 1976). Malathion (0.05%) applied @ 1,450 l/ha on mustard gave residues which were determined both by the colorimetric and TLC techniques. The average deposits in unwashed leaves with stems and pods were 3.61 and 4.51 ppm; no residues were detected after 10 days. Similarly, residues in the stems and pods on washing showed 100 % dissipation after 5 days. A maximum of 10 days is required for malathion residues to dissipate completely (Dikshit et al. 1974).

Safflower plants (78 days old) were treated with different insecticides and the residues were determined in seeds. Plants exposed to Phosalone (4.0% dust) immediately after harvest recorded highest residues (0.1 ppm). Lowest residues (0.067 ppm) were obtained in plants treated with phosphamidon (100% EC), malathion (50% dust), quinalphos (1.5% dust) and pirimicarb (50 DP and 150 DP). Residue levels of 0.075, 0.082 and 0.086 ppm were recorded in seeds treated with vamidothion (40% EC), ethiofencarb (50% EC) and endosulfan (4.0% dust). None of the insecticide residues were above the tolerance limits. (Goud et al. 1981).

5.3 Carbamate Pesticides

At 93 days Virginia tobacco (*Nicotiana tabacum*) was treated with sevimol 40 LV and carbaryl 50% w.p. @ 0.75 and 1.25 kg a.i./ha twice at an interval of 14 days. The cumulative deposits of carbaryl in or on green flue-cured leaves varied from 136.6 to 313.6 ppm and 15.2 to 33.9 ppm respectively, and then dissipated fairly rapidly. The residues reached below the tolerance limit of 3.0 ppm within 14–21 days in cured tobacco and 42 days in green tobacco. The half-life varied from 6–8 days (Singh et al. 1982). Aldicarb applied to soil in the form of 10% granules of 15 kg/ha persistes in tobacco plants for 36 days (Ramprasad & Joshi 1974).

The residue level of carbofuran applied to soyabean at 3% level was approximately 2 ppm in leaves after 25 days of application which further degraded to undectable levels after 65 days (Handa et al. 1977).

Mustard was exposed to carbofuran @ 1.5 gm a.i./metre row in furrows in soil and about 3 weeks before harvesting was given a 0.07% endosulfan spray @ 1,100 l/ha. The residues of carbofuran in unirrigated plots in 15 day old plants averaged 2.0 ppm, increased to 3.4 ppm in 30 days but dropped to 0.8 ppm on the 60th day. The residues in plant from irrigated plots averaged 1.9 ppm on 45th day and 0.9 ppm on 60th day. No detectable amounts were found in seeds at harvest (Handa et al. 1980).

5.4 Fungicides

Soil organic matter is a potential absorber of PCNB. The half-life of the fungicide in the soil varies from 15.40 days to 153 days. Carboxin was rapidly absorbed by sugarcane and was degraded in the plant within 7 days (Agnihotri et al. 1973). Two of the degraded products of benomyl, viz. methyl-2-benzimidazole carbamate and the other unidentified (YRf-0.30) were found up to 45 and 15 days respectively (Kannaiyan et al. 1975). Tridemorph was degraded rapidly on tea leaves to levels of<0.1 ppm in 14 days (Venkataraman 1977).

6 Pesticide Residues in Stored Gains

6.1 Malathion

Malathion is extensively used in protecting the grains from insects pests. It is one of the most effective grain protectant (Krishnaiah et al. 1976).

Pesticide residues were determined in wheat grains stored in the Food Corporation of India (FCI) godowns, in Punjab. Twenty samples were collected from various godowns, and nearly all the samples contained malathion ranging from 0.3 to 11.9 ppm. Four samples showed residues higher than the tolerance limit of 3 ppm (Bindra et al. 1973). In another godown, after 15 spray applications of 0.1 % malathion on wheat and rice, it was found that they contained an average residues of 1.4 and 1.0 ppm respectively. The above values were less than the tolerance levels (Agnihotri et al. 1975). At 33 ppm dosage of malathion mean residues in wheat stored for 3 months were 7.4 ppm as against 5.7 in wheat stored in 6 months. Average residues at 44 ppm dosage were 12.7 and 11.00 ppm after 3 and 6 months respectively. However, the residues from the 11 and 22 ppm dosages reached the 8 ppm tolerance level in the same period (Udeean & Bindra 1971). The study revealed that the incidence of higher residues during storage was due to low storage temperature and moisture content of the grains. At dosages of 30 and 50 ppm, the tolerance limit of 3 ppm prescribed by Government of India was reached in 5 and 9 months at the respective dosages (Chowla & Bindra 1973) giving a half-life of 2–3 months. Under conditions of high temparature and humidity during storage, 50 % of malathion on wheat, maize and pulses degraded in 1–3 months (Udeean & Bindra 1971; Kookherjee, et al. 1965; and Bindra & Siddhu 1972). Residues of malathion dissipated by 75 % in *chapattis* prepared from wheat flour. Nearly 80 % dissipation of malathion was observed during the usual processing of *chapattis* from wheat flour mixed with 8 ppm malathion. Organoleptic evaluation of the *chapattis* indicated a slight preference over the control. This preference was attributable to the faint garlic odour developed in *chapattis* (Godavaribai et al. 1960). Malathion residues were determined in rice and wheat during washing, baking and cooking. The water analysed after washing of the rice samples contained 20 % residues while cooked rice showed residue levels between 1–2 % of the original deposits. After baking of *chapattis,* barely 14–15 % of the residues still persisted. When water contaminated with pesticide was boiled for 30 min, most of the chemical was found to have been dissipated (Mukherji et al. 1973).

Husked rice, wheat, maize and pearl millet grains were treated with malathion at dosage rates 20, 30 and 50 ppm. The samples of grain were given low temperature treatment and finally processed. Residue determination showed that the bran contained the major portion of the residue. Flour had residues below the tolerance limit which were reduced further during *chapattis* making. Washing of pearl millet grains could reduce the residues by > 90 % however the unwashed samples had higher residues both in a flour and *chapattis.* In husked rice, husk removed 90 % of the residues, the rice itself had negligible amounts which disappeared during boiling (Udeean & Bindra 1973).

In order to determine residual toxicity of malathion and its efficacy in controlling flour beetle (*Tribolium castaneum*), wheat flour was mixed with 8, 16 and 32 ppm levels of malathion and stored in A-twill jute sacklets. The samples were analysed at the end of 2, 4, 6, 8, 12 and 16 weeks after storage. From the initial malathion concentrations of 8, 16 and 32 ppm, the concentrations at the end of 4 weeks were 3.7, 8.3 and 18.2 ppm respectively, which finally dissipated to 0, 1.6 and 3.8 ppm respectively at the end of 16 weeks. Comparative studies were made using porcelain tiles which were sprayed with malathion @ 40 mg/Sq. ft. There was rapid loss of malathion from porcelain tiles and with in a period of 8 weeks it reached a level which was 3% of the original concentration (Godavaribai et al. 1960).

Poultry feed sprayed with 0.08% and 0.16% malathion emulsion (50%) gave residues which degraded up to 63% and 64% respectively after 2 months of feeding the chicks. The biological half-life was reported to be 30 days (Kumari & Nair 1978).

6.2 Fenitrothion

Wheat and rice grains stored in the Food Corporation of India and Central Warehousing Corporation godowns were sprayed with fenitrothion @ 0.15 g a.i./sqm. Three days after the treatment, the residues were in the range of 2.0 to 3.5 ppm in wheat and 0.8 to 1.0 ppm in rice. These values were below the tolerance limit of the pesticide fixed by FAO/WHO for food grains. However, tnese values were above the tolerance limit of fenitrothion fixed by preventhion of Food Adulteration Act (India) (0.02 and 0.006 ppm) in food grains and milled products (Kumar et al. 1982).

GLC analysis of dried paddy straw collected from village farms showed that the fenitrothion content ranged from 0.26 to 1.96 ppm in fifteen farm samples out of the 36 samples analysed (Nandakumar et al. 1981).

6.3 Fumigants

Fumigants have no residual effects but their reactivity with the components of food may give rise to secondary and teritary conjugated break-down products (Majumdar 1973). Methyl bromide, one of the most popular fumigant forms water-soluble bromides, a series of methylated protein derivatives and gives some odour (Majumdar 1962).Fumigation with aluminium phosphide has recently been found to have led to a number of deaths in parts of Rajasthan and Madhya Pradesh. Phosphine released by aluminium phosphide has shown irreversible sorption with commodities. Black gram showed cent per cent sorption at all doses, suggesting the possibility that protein rich foods absorb phosphine to a great extent.

7. Organo Chlorine Pesticide Residues in Random Samples of Food Grains and other Articles of Food

7.1 Raw Food Articles

DDT residues were determined in market samples of potatoes from Calcutta (Mitra & Roy 1955) and brinjal and tomatoes from Ludhiana (Jaglan & Chopra 1970). The residues detected were below the tolerance limit prescribed by other countries.

In a study spread over a period of 7 years, a large number of samples of cereals, pulses, oilseeds, vegetables, grapes, milk, egg, fish, meat, etc. from Hyderabad market were examined. DDT was found in 655 samples out of the 1,316 samples analysed and in some, the amount of pesticide exceeded two WHO tolerance limit (Lakshminarayana & Krishna Menon 1975). In another study from Hyderabad, 143 samples comprising of cereals, egg, meat, milk and pulses were found to be contaminated with pesticides, of which DDT was found in 94 samples. Out of the rate 94 samples, 70 had DDT residues higher than the tolerance limit prescribed by the U.S. Food and Drug Administration (Lakshminarayana & Krishna Menon 1972).

Maize, wheat, wheat bran, gram, barley, polished rice, groundnut cake at seed husks contained DDT residues in the range (0.08 to 0.8 ppm). Other cattle feed like wheat *Bhoosa* had traces to 0.45 ppm of DDT (Sastry & Singh 1978). In Pantnagar, DDT levels in wheat were found to be 0.41 ± 0.23 ppm (Tripathi 1966). Pesticide residues were also determined in wheat grains from villages and grain *Mandis* of Punjab. Of the 43 samples collected, 21 contained pesticides of which 17 showed DDT residues (Bindra et al. 1973).

DDT and HCH residues were determined in contaminated wheat flour and after making *Chapattis* on a hot iron plate. The level of DDT were almost the same in flour (0.13 ppm) and *Chapattis* (0.11 ppm). On the other hand, the loss of HCH residues in fresh *Chapattis* was 35–50% as compared to wheat flour (Chawla et al. 1979b). However in another study, it was observed that the major part of the DDT, lindane and malathion residues present in rice and what is lost during cooking of the former and baking of the latter as *Chapattis*. Only traces were found to persist (Mukherjee et al. 1973).

Pesticide concentrations were investigated in 390 raw samples of food stuffs. High concentrations of DDT (2.1 ppm) were usually found in cereals and pulses (Mukherjee et al. 1980).

Different summer and winter vegetable samples from Hissar market revealed 33 (23.6%) out of the 140 samples to be contamination by DDT, BHC and endosulfan. Of the suspected samples, 12.1% were contaminated with DDT, 64% with BHC and 24% with endosulfan. The highest contamination (62.5%) of these insecticides was in the samples of Okra (*Abelmoschus esculentus*) followed by tomato (*Lycopersicum esculentum*) and Chilli (*Capsicum frutescens*) where it was 50% (Dahiya & Chauhan 1982).

Much higher (10.5–20.0 ppm) residue levels of HCH were detected in leafy vegetables from Mysore. Samples analyzed included *Chenopodium album, Trigonella foenumgraceem, Amaranthus polygamus, Spinacia oleracea, Amaranthus gangeticus* and *Amaranthus peniculatus.* Acid treatment coupled with steam cooking brought down the levels (Viswesariah & Jayaram 1972).

7.2 Vegetable Oils

High fat food such as eggs, milk oils and oilseeds sold in Delhi markets revealed the presence of DDT residues (Dewan 1965). The residue levels ranged from 5.0 to 25.7 ppm in oils and 1.1 to 4.1 ppm in oil seeds collected from Delhi (Thakare et al. 1969). In another survey of groundnut, mustard, sesame and coconut oils from Delhi markets, DDT varied from 5.7 to 25.7 ppm (Agnihotri et al. 1974a).

Analysis 60 samples of oil from the local markets of Lucknow and Sitapur revealed that the range of contamination of groundnut oil with HCH is more in the samples collected from Lucknow (0.199–6.421 ppm) than those from Sitapur (0.3–2.4 ppm). Aldrin residues in the samples collected from Sitapur were about 4 times the levels found in Lucknow. Total DDT levels were also higher in Sitapur (3.0 ppm) than in Lucknow (2.0 ppm) (Srivastava et al. 1983).

Residues of organochlorine pesticides have also been estimated in samples of mustard, hydrogenated vegetable and coconut oils collected randomly from markets of Lucknow. Besides DDT and DDE, HCH isomers were frequently detected in significant concentrations in all the three oils (Siddiqui et al. 1980–81).

7.3 Fodder Grass

Some species of fodder grasses in common use as cattle feed were collected for pesticide residue analysis. All samples were found to contain DDT residues. Total DDT levels ranged from 0.2 to 0.6 mg/kg. pp'-DDT was found to be the main contaminant (Kaphalia & Seth 1982).

7.4 Wheat and market Samples of Vegetable

Samples of wheat collected from Bombay markets revealed that aldrin residue levels in wheat were in the range of 0.50–0.08 ppm. Of the 18 samples contaminated, with aldrin, two had residues above tolerance limit prescribed by WHO. Aldrin residues in different vegetables, cereals and grains have been documented earlier (Saha 1969), Agnihothrudu & Mithyanatha (1978) and Bindra & Kalra (1973). Six of the eight market samples of okra contained 0.05 to 0.3 ppm of endrin (Bhalla et al. 1970).

7.5 Eggs

Twenty five egg samples collected from Bombay markets showed a high incidence of contamination with DDT, BHC, lindane, dieldrin, heptachlor and aldrin, the respective residue levels being 0.48–2.10 ppm, 0.14–1.01 ppm, 0.12–0.78 ppm, 0.61–1.04 ppm 0.05–0.60 ppm, and 0.14–0.52 ppm (Banerji 1979). Farm eggs and also those from home-raised hens from Lucknow region were examined for organo-chlorine pesticide residues. The concentration was higher in the york. The content of DDT, HCH and aldrin in the farm egg was 18.5, 4.6 and 0.93 μg per egg respectively whereas eggs laid by domestic birds had 7,4, 4.1 and 0.39 μg/egg of DDT, HCH and aldrin respectively. (Siddiqui et al. 1981). These findings are at variance with the findings of an earlier Delhi survey where only 30% egg samples (shell free) were found to be contaminated with DDT (Agnihotri et al. 1974a).

7.6 Fish and Crabs

Analysis of pomfret fish obtained from the Arabian Sea near Bombay revealed that 18 out of 25 samples had pesticide residues. Among the pesticides detected DDT was present at the highest level (0.4 and 0.9 ppm) in the liver and kidney samples respectively. In the grills and muscles, the DDT concentration was also the highest being 0.5 and 0.4 ppm respectively (Bhinge & Bannerji 1981). The concentration of lindane, heptachlor dieldrin, aldrin and BHC in fish muscles was 0.017–0.036 ppm, 0.05–0.075 ppm, 0.03 ppm, 0.03–0.04 ppm, and 0.004–0.36 ppm respectively. This study showed that DDT is accumulated at a faster rate than other organochlorine pesticides. GLC analysis of the crabs which are commonly consumed in some regions of Malnad, Karnataka show the presence 7 of DDT in the range of 110–2500 ppb (Bhat & Krishnamachari 1977).

7.7 Meat Products

Adipose tissues of goats slaughtered in Delhi also carried low levels of DDT (0.5–1.6 ppm) (Sharma et al. 1979). Low concentration of DDT (0.538 ppm) were also noted in the fat tissue of food animals of Pantnagar (Tripathi 1966).

Monitoring of DDT residues was done in sheep used in animals experiments. Two different levels 300 and 1,000 ppm of DDT incorporated in a concentrate mixture were fed over a period of 23 and 14 weeks respectively. Meat, liver and fat collected from animals slaughtered at the end of the feeding period contained 1.67, 0.28 and 18.86 and 2.23, 0.21 and 27.7 ppm DDT respectively (Sastry & Singh 1978). Based on this a suggestion has been made that DDT residues in meat may not be hazards if animals are used for food purposes 4 weeks after withdrawal of the contaminated feed.

Muscle, liver, brain, abdominal body fat and bonemarrow samples of goat, buffalo and chicken, analysed for residues of DDT and HCH showed relatively high residue levels in body fat and bone marrow compared to other tissues. DDT and HCH residues were highest in chicken body fat, averaging 4.2 ppm DDT and 3.9 ppm BHC. DDT content was much higher in goat and buffalo bone marrow than in the corresponding body fat. DDT levels in brain samples were highest in buffalo (0.14 ppm). Overall DDT levels in goat were lowest. Greater accumulations of DDT and HCH were found in leg muscles than in breast muscles of chickens (Kaphalia & Seth 1981).

The levels of total DDT were comparable in skeletal muscles and body fat of sheep from Rajasthan (0.023 ppm) and Kashmir (0.020 ppm). However, the analysis of body fat samples of sheep revealed that animals from Rajasthan had relatively high contamination of DDT as compared to those from Srinagar. These levels were however below the tolerance limits prescribed by FAO/WHO (Seth & Kaphalia 1983).

HCH levels in 45 samples of body fat, skeletal muscle and blood plasma of sheep collected from Srinagar were measured. Maximum number of samples were found to contain residues between 0.05 and 0.1 ppm in the skeletal muscles and above 0.2 ppm in body fat samples. The blood plasma contained residues below 0.05 ppm in all the samples. These values were below permissible concentrations proposed by FAO/WHO (Seth & Kaphalia 1981).

7.8 Wild Birds

Residues of HCH and DDT were assessed in the internal body organs, depot fat and blood plasma of a few species of Indian wild birds captured in and around the urban areas of Lucknow. Total DDT levels were 0.59, 20.32, 50, 78, 67.01 and 93.35 ppm in depot fat of chicken, cattle egret, crow, kite and vulture respectively. In other tissues total residues of DDT were encountered in the following decreasing order: Chicken pigeon cattle egret crow kite vulture. In blood plasma of chicken, pigeon, cattle egret, crow, kite and vulture total DDT detected was 0.01, 0.01, 0.04, 0.07, 0.54 and 0.51 ppm respectively while in brain tissues of these animals the respective values were 0:01, 0.02, 0.04, 0.07, 0.08 and 1.42 ppm. The total DDT concentration in Pigeon ovary was 0.01 ppm. As compared to blood plasma levels, brain tissue of crow and pigeon was found to have relatively high levels of total HCH. Values of total HCH and γ-HCH in the brain tissue of the vulture were 1.25 and 0.34 ppm. These values were many times higher than those present in other species of birds. As high as 29.73 ppm (average 22.49 ppm) total HCH was recorded in the depot fat of the crow. In farm-bred chickens which were taken for comparison, the mean values of total HCH and γ-HCH were lowest. Am internal body organs, total HCH levels were high in liver, heart, lung and kidney of pigeons and crows. Accumulation of total HCH in breast muscles and spleen was relatively high in vultures than kite and cattle regret. Concentration of γ-HCH was maximum in these birds as compared to other isomers. Levels of α-isomer were maximum in the brain tissue of all the birds studied (Kaphalia et al. 1981).

7.9 Milk & Milk Products

Fifty specimens each of buffalo and goat milk were analyzed for contamination of organo chlorine pesticides. Average concentrations of total DDT in buffalo and goat milk were 0.049 and 0.042 ppm while that of HCH and aldrin, was 0.057 and 0.041 ppm respectively (Saxena & Siddiqui 1982).

A heavy spray (1 gm/m^2) of DDT on the roofs and walls of houses led to the contamination of the cattle feed as at Ludhiana, Punjab, India which inturn led to high levels of residues in milk samples (Dhaliwal & Kalra 1977). Out of the 23 samples of milk from rural areas, 21 contained 0.019 to 1.09 ppm of DDT and its derivatives whereas samples from urban areas, however, contained lower levels (range: 0.02 to 0.28 ppm) pp'-TDE was the most prominent metabolite.

In contrast, milk samples from Delhi contained residues of pp'-DDT only (Agnihotri et al. 1974a). Analysis carried out during 1965 and 1972 revealed that within a period of 7 years there was nearly 3.3 times increase in the concentration of DDT in milk samples examined in Delhi. Fifty three per cent of the samples contained DDT above the tolerance limit set by FAO/WHO.

Samples of milk and butter collected from Pantnagar contained 0.0032–0.0026 and 0.04–0.14 ppm DDT respectively (Tripathi 1966). In another study of milk products (butter and infant formula) from different parts of India, pp'-DDT contributed to the main bulk of the residue (Dhaliwal & Kalra 1978). Samples of butter collected from Punjab, Haryana, Delhi, Rajasthan and Gujarat were contaminated; the range of DDT was 0.42 to 11.36 ppm, 90% samples exceeding the FAO/WHO tolerance limit of 1.25 ppm. The concentration of DDT in four popular infant formula varied from 1.52 to 2.72 ppm (average 1.90 ppm). This finding is of great significance as the consumption of milk by a 3 month -old child weighing approximately 5 kg and at a normal feeding rate of 135 g/day would result in a daily intake of 47 μg of DDT (FAO/WHO 1973). Even the spray-drying process of manufacture of infant formula does not eliminate the presence of high levels of DDT.

Milk samples from buffalo were collected from randomly selected rural areas of Ludhiana, Jullundur, Ferozepur and Sangrur districts of Punjab. All the samples analysed showed the presence of residues of both DDT and HCH. pp'-TDE, pp'-DDT accounted for the major content (Kapoor et al. 1980).

8. Organo Chlorine Pesticide Residues in Human Tissues

8.1 Human Fat

Relatively high levels of DDT and its metabolities have been reported in the body fat (12.8 to 31.0 ppm) of the Indian population (ICAR, 1967). Admittedly, considerable differences are likely to be seen in the residue levels of pesticides within different regions of the country (Bhaskaran et al. 1979).

In a study of 69 body fat samples collected from Delhi, the mean for total DDT derived material was 32.1 ppm (Dale et al. 1965). DDT was present in greater amount than DDE in 60 out of 67 individual fat samples of group I, in 14 out of the 19 samples of group II and in 10 out of the 16 samples of group III. DDE calculated as DDT averaged 39, 34 and 37% of the total DDT derived materials in groups I, II and III respectively.

High concentrations of DDT were reported in yet another study from Delhi following analysis of body fat of 94 subjects including 8 children below the age of 5 years (Ramachandran et al. 1973; 1974). Total DDT varied from 0.17 to 176.5 mg/kg of body fat (average: 21.8–2.9 mg/kg of body fat). With the exception of two, all samples contained DDE, pp'-DDT and op'-DDT.

In a country-wide survey done in eastern, and southern regions, monitoring of pesticides was done in human fat samples. DDT residues were measured in 45 human fat samples collected from the population at Calcutta. The mean levels of total DDT and BHC (alpha, beta and gamma isomers) were 6.25 ppm and 1.62 ppm respectively. Males were found to store more DDT residues (6.91 ppm) than females (4.45 ppm) (Gupta et al. 1980b). Comparable results were obtained in 116 autopsy human fat samples of the general population of Bangalore. The mean values of the total DDT and BHC were 7.82 ppm and 5.05 ppm respectively. The two isomers pp'-DDT and op'-DDT contributed more for the total DDT. Also the males were found to have higher DDT residues (8.72 ppm) than females (5.97 ppm) (Gupta et al. 1982).

Analysis of human fat, liver, kidney spleen and brain samples taken from 100 individual who died accidentally or by suicide/homicide from November 1975—October 1976 in Calcutta, revealed that the highest mean concentration of DDT (0.66 ppm) in adipose tissue was found in the 21–40 years age group while that of lindane (1.5 ppm) in the 61 year and above age group. The overall mean concentration of DDT and lindane in fatty tissue was 0.46 ppm and 0.45 ppm respectively. DDT was not detected in the spleen and brain. Not a single sample of adipose tissue was positive for malathion. (Mukherjee et al. 1980).

Analysis of adipose tissues of human subjects (10 to 60 years old males) taken from areas in and around Lucknow showed DDT levels indicating a decreasing trend as compared to the Delhi studies (Siddiqui et al. 1981c).

Another study from Delhi region revealed that the average values for total DDT and DDE in 14 human fat samples was 4.7 ppm (range 2–10–1 ppm) (Bhaskaran et al. 1979).

All the three common isomers of HCH (alpha, beta and gamma) were detected in six samples of adipose tissue of normal young persons from Lucknow (Kaphalia & Seth 1979). Mean concentrations of lindane, total HCH and DDT were 0.0776 ppm, 2.334 ppm and 1.754 ppm respectively (Kaphalia & Seth 1983).

8.2 Human Blood

Venous blood samples collected during 1977–78 in and around Coimbatore city, 55 from people living in the urban area, 19 from persons working in the pesticide manufacturing factories and the rest from the agricultural labourers working in the pesticide sprayed fields were analysed for DDT residues. The general urban population had the least concentration of the pesticides (total value for the male 0.196 mg/l and for the female 0.247 mg/l). Compared to the general urban population, the agricultural worker showed a greater accumulation (2.324 and 2.767 mg/l respectively for female and male respectively). Labourers from the pesticide manufacturing factories showed an extremely high concentration in blood (4.394 in males and 3.031 mg/l of total pp′-DDT in females) (Balasubramanian & Sundararajulu 1978).

In a similar study of residents of Delhi, 174 out of 182 were found to contain residual DDT in their blood (Agarwal et al. 1976). The average total DDT concentration in the whole blood ranged from 0.177 to 0.683 mg/l in males and 0.166 to 0.329 mg/l in females. Metabolites detected were pp′-DDE, pp′-DDD and op′-DDT, DDE accounting for most of the total DDT.

A comparative study of DDT metabolite levels in the blood of one Indian, three Swedish and one Kenyan revealed that the Indian had the highest level of pp′-DDE, while in the Swedish and the Kenyan these levels were below detection limits (Gupta et al. 1977).

Analysis of samples of blood plasma and cerebrospinal fluid from outdoor and indoor patients admitted to Lucknow hospitals revealed that of the total DDT detected, 67–70% was present as pp′-DDE, whereas in the case of BHC, all the three common isomers were detected frequently. The average values of total DDT and BHC were 27.5 and 74.7 ppb and 196.6 and 295.9 ppb in blood plasma of normal population and exposed groups respectively. In cerebrospinal fluid of children, traces of lindane were observed in two samples only while DDT was absent in all tested samples (Kaphalia & Seth 1979).

DDT and HCH residues were detected in all the 99 samples of blood plasma of normal males, females and children and exposed males belonging to urban Lucknow. Average concentrations of total HCH in blood plasma of children (0.038 ppm) and females (0.034 ppm) were comparable although in males it was almost twice value (0.075 ppm). γ HCH levels in children (0.016 ppm) were higher than in females (0.012 ppm). The average concentration of total HCH in males exposed to HCH in a formulating plant (0.295 ppm) was almost 4 times the concentrations in male of the general population. γ HCH in exposed males (0.043 ppm) was almost three and a half times the concentrations in non-exposed males (0.012 ppm). Average concentrations of total DDT in blood plasma of children (0.023 ppm) and females (0.023 ppm) was the same but was higher in the case of males (0.028 ppm). Average total DDT in blood plasma of exposed males was about seven times (0.2 ppm) that of non-exposed males (Kaphalia & Seth 1983).

Studies on the blood serum of 20 workers occupationally exposed to DDT for an average duration of 14 years revealed the presence of significant levels of BHC and different isomers of DDT. Total DDT residues were about 10 times of those of controls. Levels of BHC in controls was 2.3 times that of levels workers exposed to DDT only (Siddiqui et al. 1981c).

8.3 Pregnant Mothers and Still Births

In an exploratory study carried out in collaboration with the queen Mary's Hospital, K.G's Medical College, Lucknow, samples of placenta and accompanying fluid collected from 50 pregnant women in and around Lucknow were analysed for residues of organochorine pesticides. pp'-DDE, pp'-DDT, aldrin, dieldrin and isomers of HCH were frequently detected in both the specimens. The study was extended to 100 pregnant women and residues were determined in maternal blood, placental tissue and umbilical cord blood. Concentrations of pesticides were highest in maternal blood and lowest in umbilical cord blood. Residues levels of DDT and its metabolites were detected in all the samples analysed, indicating their possible prenatal transfer to foetus. A rough correlation was found to exist between the pesticide concentration and age, dietetic habits and area of residence of pregnant women. These studies suggest that DDT in blood of new born babies is slightly less than found in mothers indicating that placenta excludes some but not all the DDT transported across its barrier (Saxena et al. 1980b).

HCH (alpha, beta and gamma isomers) were detected in maternal and cord blood collected 24–48 hr after child birth in nursing Indian mothers. The mean residue levels of total HCH in maternal blood were 0.022 while in umbilical cord blood, the residue levels were 0.03 ppm. Total DDT levels in maternal blood and umbilical cord blood in this study were 0.02 ppm and 0.01 ppm respectively (Siddiqui et al. 1981a).

Considerably high amounts of organochlorine pesticides (DDT, HCH and aldrin) residues were detected in samples of the circulating blood and placental tissue of women undergoing abortion or premature labour as compared to pregnant women in full-term labour. Relatively higher levels of organochlorine pesticides, specially DDT and DDE in case of abortions as compared to premature labour suggest their possible involvement in the termination of pregnancy. As a follow up study, HCH, aldrin, pp'-DDD and pp'-DDT were measured in the blood, placenta and foetus discharged by women experiencing spontaneous abortions, pre-term labour or full-term labour and the trend was found to be in the order : spontaneous abortion pre-term full-term. The results also suggest that organochlorine pesticides possibly act as antagonists to full term pregnancy and normal delivery (Sexena et al. 1980a, 1981b).

Specimens of breast milk collected from lactating mothers 24–48hr after child birth in and around Lucknow were analysed for pesticide residues. The mean levels of total DDT, BHC, lindane and aldrin were found to be 0.2 ppm, 0.1 ppm 0.04 ppm and 0.03 ppm respectively. Neonates consuming whole breast milk are exposed to a daily intake of about 108.6 ppm and 91.975 ppm of total DDT and HCH respectively

(Siddiqui et al. 1981 b) which is far greater than 0.01 mg/kg/day, the maximum safe intake of DDT, recommended by WHO.

Human milk collected from 75 lactating women in the Punjab showed the presence of DDT and BHC residues in all the samples analysed. The mean level of residues for pp'-DDE, pp'-DDT and total DDT were 0.25, 0.26 and 0.51 ppm respectively. The mean level of total DDT (0.51 ppm) found in human milk in India is more than the level reported from USA, Canada, Europe and Australia (Kalra & Chawla 1981). Fifty specimeans of human breast milk collected from lactating mothers in the Queen Mary's Hospital, Lucknow were analysed for organochlorine residues. Mean total DDT was 0.52 ppm and mean HCH 0.2 and aldrin. 0.04 ppm (Saxena & Siddiqui 1982).

8.4 GEMS Study on Pesticides in Human Breast Milk

The above data have to be viewed against a recently concluded international study of the assessment of human exposure to organochlorine pesticides through biological monitoring commissioned by the Global Environmental Monitoring System (GEMS) set up jointly by the United Nations Environment Programme and the World Health Organization (Slorach & Vaz 1983). The median levels of p. p'—DDT reported in the fat of human milk by the participating institution in China, India and Mexico (1.8, 1.1 and 0.71 mg/kg respectively) are several fold higher than those reported from the other participating countries (highest median level 0.25 mg/kg fat—Federal Republic of Germany). Both the USA and Sweden reported median levels were below 0.1 mg/kg fat. The report concludes that the relatively high levels reported by China, India and Mexico and almost certainly due to the continuing use of DDT as an insecticide in agriculture and for vector control in public health. The median levels of p.p'-DDE, the major metabolite of p.p'-DDT in China, India and Mexico (4.4, 4.8 and 3.7 mg/kg respectively) are markedly higher than those reported from the other participating countries.

The median levels of β-HCH reported in the fat of breast milk in China and India (6.6 and 4.6 mg/kg respectively) are much higher then the values reported from the other participating countries. This is almost certainly due to the previous and continuing use of technical HCH of which β-HCH is minor but most persistent in agriculture for public health programmes. The samples analysed in this Quality Assessment Programme were drawn from the same geographical region within the country and are obviously not representative of the whole country.

9. Ecotoxicology of Pesticides

9.1 Ecological Implications

Pesticides have to be recognized as non-specific poisons. They have been used and continue to be used because they are effective in reducing the population of one or more pest species. Different species within one ecosystem exhibit widely different degrees of vulnerability and susceptibility to pesticides. The biochemical mechanism of action of pesticides varies from one compound to another and no pesticide can be considered as selective in its mode of action to be toxic to only one species (Corbett 1974; Moriarty 1975; Krishna Murti 1980). Hence the ecological risk inherent to pesticides.

For exclusive action on one pest species, the amount of pesticide that reaches other species both directly from the non-living environment and indirectly through the food must be controlled. Indiscriminate or misuse of pesticides upsets the pathway and distribution of pesticides in the ecosystem. A single application of a pesticide may not reduce the numbers of pests and non pests for too long a period. The speed with which a population recovers from the toxic effect of a pesticide will depend on its reproductive and immigration rates and also to what extent the predators, the prey or the competitors of the species have been exposed and affected.

Another serious aspect of pesticides is their property to cause the resurgence of pest populations which require much higher doses of the chemical to become susceptible and the appearance of new pest species and the development of genetic resistance (Ripper 1956; Dempster 1975; Brown 1976, 1977, De Foliant 1982).

9.2 Vectors in Public Health

In no other area of application, pesticides have caused as much concern as in the control of vector-borne diseases in the Public Health Sector. The Majority of arthropod-borne disease agents are "*Zooanthroponoses,* i.e., disease agents perpetuated in wild vertebrate-arthropod cycles that infect man only incidentally" (De Foliant 1982). By transgressing into the orbit of the wild life cycles man invites upon himself infection. Occasionally they appear in epidemic dimensions in the human habitat due presumably to ecological disturbances triggered by human activity.

The enzootic foci of most of these zooanthroponoses are widely dispersed globally. It will be unrealistic to believe that they could be eliminated altogether in the foreseeable future even with all the available chemical weapons. A good surveillance system is an absolute must as one of the defence line against such epidemics. When a threat of an epidemic poses itself, there should be, furthermore, total readiness to quickly mobilize all the resources of vector control technology. In this context, we must remind ourselves of the following significant events of recent history. Malaria was reduced in India from 750 million cases and 750,000 deaths per year prior to 1953 to only 100,00 cases per year during the mid 1960's (Wattal 1971). However, a resurgence to 5 million cases in 1976 and to 10 million cases during the first 9 months of 1977 shook our confidence in the early strategy (Akhtar & Learmonth 1977). Furthermore 122 million people are at the risk of filariasis (Wattal 1971).

Disease agents transmissible directly from man to man via an arthropod vector are generally more amenable to elimination or containment. However, the challenges posed by them are manifest as the resurgence of malaria and the recurring epidemic of dengue. Admittedly, the state of art of medical entomology today does not permit complacency. Add to this the increasing number of different arthropod-borne vertebrate-pathogenic entities and the variety of habitats and life cycle of their vectors. Near about 400 arboviruses transmitted by mosquitoes and some by ticks have been identified of which 100 appear to be associated with human disease (Berge 1975). Four of the six tropical diseases afflicting more than 600 million people worldwide are arthropod-borne: malaria, filariasis, leishmariasis and trypanosomiasis. In the words of De Foliant "this "Tropical Big Four" is composed of more than a dozen different parasites and literally scores of different epidemiological entities"

9.3 Pesticides in Vector Control

The strategy for *eradication of malaria* now revised as *control of malaria* (WHO 1978) was derived from the assumption that plasmodial infection in the human population will disappear within 2–3 years in a given area if mosquito transmission can be interrupted for that length of time. Most malaria transmission takes place inside houses at night and hence the main method of attack has been the application of residual pesticides to the inside walls of domiciles.

In actual practice the attack phase with insecticides lasted longer than expected due to various reasons minimising the chances of direct elimination. Most importantly, major vector species developed resistance to a succession of insecticides used as intradomiciliary sprays. Thus DDT resistance has developed in populations of 15 anopheline vector species and dieldrin resistance in populations of 35 species (Brown et al, 1976 and Krishna Murti 1982). *Anophelas culicifacies, Anophelas stephensi, Anophelas fluviatilis* and *Anophelas philippinensis* have in India become resistant to DDT and the first two for BHC and dieldrin (Brown et al. 1976; Sharma 1972). *Anophelas culicifacies* has also started showing resistance to malathion (Rajagopal 1977).

The emergence of large scale resistance not only in India but in Latin America can be attributed to the role of agricultural pesticides in bringing selection pressure on important disease vectors. Thus the malation and propoxur resistance of *Anophelas albimanus* in El Salvador has been mainly induced by the use of malathion, methyl parathion and carbaryl on cotton fields (Georghiou 1972). As resistance appears, substitution becomes expensive as illustrated by the studies in India against *Anophelas culicifaciens*. Three rounds of fenitrothion are required now to cover one malaria transmission season compared to two rounds of DDT (Bhatnagar et al. 1974).

The frustration faced by public health scientists in the chemical control is aptly summarised by Copplestone (1981):

> The role of the mosquito as a vector of human disease is fascinating and important. The ways in which the parasite have come to terms with their two hosts (mosquitoes and humans) and have used the life cycle and behaviour of various species of

mosquito to ensure their survival form a biological puzzle which must be solved before control can be effective. The solution, unfortunately, is far from complete".

Although only 10% of the total production of pesticides is used in public health, there is need for much greater caution and therefore more intensive field studies on chemicals to be used in public health than those employed in agriculture. The general public is in intimate contact with the pesticides used for vector control in public health because their homes are sprayed. The very old, the very young, the sick and the pregnant are all likely to be exposed. Applicators are exposed for much longer periods of time as in malaria control campaign, where the spraymen may be exposed for 6 days a week for many months. To this we must add the complexity of the intake from food. The compounds currently used for mosquito control include:

> DDT—for adults when the species retains sensitivity. This would presuppose the availability of test techniques in the area sprayed for determining sensitivity and resistance.
>
> Malathion, fenitrothion and propoxur—in areas where resistance to DDT has developed. This presupposes a surveillance system of trained entomologists and technicians to test cross resistance etc.
>
> Malathion and fenitrothion have been used for aerial application to control outbreaks of dangue haemorrhagic fever. Usually the vector reservoirs are agricultural fields or forests. Aerial spraying presupposes the existence of expertise to assess the ecological impact of such operations.
>
> Fenthion and Chlorpyrifes for larval control in foul waters not likely to be used for drinking.

The need for continued vigilance in the trial period of these compounds became evident with the outbreak of poisoning among spraymen in Pakistan applying malathion. The active ingredient polymerized to give a more toxic product when the material used for spraying was stored under faulty conditions (Baker et al. 1978). With the pressing demand for more pesticides, there is every likelihood of the proliferation of their manufacture under uncontrolled conditions. Slight differences in the techniques employed for formulation or inadvertent impurities can profoundly alter the toxicity profile of the chemicals.

9.4 Pesticides in Agriculture

Use patterns of pesticides, good agricultural practice and the problem of pesticide residues in food are closely interrelated. Since chemical control of pests in agriculture will remain part of the Integrated Pest Management for the foreseeable future, it is of utmost importance to enunciate principles for the proper use of pesticides in preharvest practices and harvesting, marketing, transporting and storage of foodstuffs (Bates 1981, 1979). The concept of *good agricultural practice* is based on many interrelated factors and functions. One has to maintain a balance between cost, productivity, quality and relative freedom from residues. One has to ensure that the pests will be controled effectively while bearing the minimum amount of residues. The Codex definition of the concept of "good agricultural practice in the use of pesticides" is worth quoting in this context:

> "good agricultural practice in the use of pesticides is the officially recommended or authorized usage of pesticides under practical conditions at any stage of production storage, transport, distribution and processing of food and other agricultural commodities, bearing in mind the variations in requirements within and between regions and taking into account the minimum quantities necessary to achieve adequate control, the pesticide being applied in such a manner as to leave residues that are the smallest amounts practicable and that are toxicologically acceptable". (FAO/WHO 1978).

The usage of pesticides must take into consideration the effect of pesticides on the environment besides the usual criteria of efficacy, toxicology and food quality in relation to public health.

There is agreement among experts all over the world that the occurrence of unintentional residues in a number of food items and animal foodstuffs is partly a result of environmental contamination. It follows, therefore that the sources of such contamination have to be discovered and eliminated in order to reduce the background level of residues. There is also increasing awareness of the extent of the use of certain persistent pesticides and hence the need to replace them by agents, the residues of which are less undesirable toxicologically (Krishna Murti 1981).

There is increasing evidence for mosquitoes developing resistance to insecticides as a result of selection by insecticides used in agriculture. A typical example is the resistance of mosquitoes in India to HCH (Wattal et al. 1981). High yielding varieties of agricultural crops are generally more susceptible to pests than wild varieties and hence pest control chemicals are used in much greater quantities in the wake of Green Revolution. Whether such use in rice cultivation in South India in recent times is linked to the resurgence of malaria in that region has been a subject of controversy (Chapin & Wasserstrom 1983 and comments by Curtis and Singh on the same). Anti-mosquito spraying itself has been implicated in resistance to pesticides (Curtis 1981; Mojamdar 1978). The following conclusion arrived at by an expert body of WHO (1976) is also relevant to this discussion:

> "It is finally becoming acknowledged that resistance is probably the biggest single obstacle in the struggle against vector-borne diseases and is mainly responsible for preventing successful malaria eradication in many Countries— Evidence has also accumulated to show conclusively that resistance in many vectors has been caused as a side-effect of agricultural pesticide usage. Thus control of selection pressure is largely out of the hands of those who use insecticides for the control of disease vectors."

9.5 Legislative Measures

No discussion on the safety of pesticides is complete without surveying the legislative measures available in the country for regulating the production, import, use and disposal of these chemicals. Poisonings, self-inflicted or accidental have helped in maintaining the bad reputation of certain pesticides. According to figures collected by WHO, nearly 500,000 people in the world are accidentally poisoned by pesticides with a fatality rate of 1%, i.e. 5000 deaths annually. Developing countries including India account for the major part of this fatality.

The episode of food poisoning which occurred in Kerala in 1958 has perhaps no parallel in the history of modern public health. Out of 828 cases of severe poisoning, over 102 deaths were reported. Incidence rate was almost 100% and fatality rate 10-15%. Folidol (bearing the name of Bayer's E605) was detected in remnants of food and stomach contents of the victims (Karunakaran 1958).

Pesticides appear to be the main agents used in the majority of medico legal cases examined in the country. A retrospective study of the registry records of the Tamilnadu State Forensic Laboratory at Madras revealed that more than 50% of viscera examined of suicide cases contained toxic pesticides (Indira Balasubramanian & C.R. Krishna Murti, unpublished observations). Case study reports of accidental poisoning of wheat and animal feed in Uttar Pradesh leading to epidemics of epilepsy have been published (Khare et al. 1977; Gupta 1975; Nag et al. 1977; Misra & Nag 1984).

The Insecticides Act, 1968 and the rules framed there under became operative from 1972. Under the Act it is compulsory to register all products at the Central level although for manufacture, formulation and sale are dealt with at the State level. The registration is not time bound and is looked after by a Registration Committee. The Government is empowered to prohibit the import, manufacture and sale of any pesticide or confiscate stocks of it if exigency demands such intervention. The enforcement machinery provides for the appointment of Analysts, Inspectors and the establishment of a Central Insecticide Laboratory and State Laboratories (Government of India 1976).

The Insecticide and Pesticide Section (Section 65) of the Prevention of Food Adulteration Act, 1954 (amended in 1976) prescribes the tolerance limit of insecticides in various types of Food (Malik 1979).

The provisions of these have enabled certain degree of control Acts on the manufacture and use of pesticides. In view of the inevitable delay (often avoidable) in clearing pending applications for registration, there has been a strong lobbying by the manufacturers to review the Insecticides Act and revise it to meet what is made out as the urgent need for pesticides for boosting production food. Periodic conferences convened by the organized sector of the industry get wide publicity in media, thanks to participation by Central Ministers and other VIP's. One of the plea made by the lobbyists is for the simplification of the procedure contained in Annexure III of the Act. Actually what is pressed for is the scrapping of the regulatry requirement to furnish detailed toxicological information and environmental safety of the chemicals to be manufactured. The plea made is that toxicological data need not be furnished on items for which the technology is from developed countries. The tests conducted in those countries should be taken as valid for India as well. Furthermore it is argued that sophisticated facilities for the safety evaluation of pesticides are not available in the country and laboratories which have the capability to undertake the relevant investigations are either not equipped or are not accessible to industry. In this context, it is gratifying to note that policy makers have not yielded so far to this demand. On the other hand Government has substantially augmented the facilities for safety evaluation of pesticides.

This, however, is not to say that there is no scope for updating the procedures currently adopted for the registration of pesticides. Risk of exposure to toxic chemicals including pesticides has been of great global concern in recent years and the Academic communities in developed countries have taken commendable initiative in making scientific studies of the problem as evident from the reports of the US National Academy of Sciences and the Royal Society of London on the risk assessment of chemicals. The Central Insecticide Board has a semi-autonomous status but has not acquired dynamism and the inherent capacity to sensitively respond to basic questions concerning the safety and future of pesticides. The Registration Committee is a semi-official body with no full time members who can devote themselves wholeheartedly to the study of the various issues. Expertise is lacking to assess critically criteria documents provided by International agencies or evolve indigenously criteria for registration based on health safety and freedom from effects on the environment (Krishna Murti 1983).

10. Conclusions

10.1 DDT-Need for a Fresh Look at Safety

DDT is the first man made insecticide to which a large percentage of our population has been exposed for over 25 years now. In spite of the fact that most of the developed countries of the west and Japan have stopped the use of DDT, we have continued to depend on it for pest control in agriculture and public health. Ever since the first study of DDT residues was made as early as 1945, voluminious data has accumulated on residue levels in food and biological tissues (See Table 8). A critical assessment of the health impact of this residue burden is long overdue.

The main justification for the continued use of DDT has been its efficacy against mosquitoes involved in the transmission of malaria. In view, however, of the emergence of resistant forms of mosquitoes in many parts of India, the total dependency on DDT for vector control is unrealistic.

On the other hand, a good deal of data has accumulated from field studies and the laboratory on residue levels and biological effects which need to be examined. The following tentative inferences drawn from these data are of relevance to the present discussion:

i) there is a disturbing state of uncertainity about the health effects of humans of the relatively heavy body burden of DDT and its metabolites;

ii) a neonate suckling its mother is ingesting everyday three to four times the admissiable daily intake of DDT (or BHC) and nothing is known about the effect of this chemical on the health of the baby during its postnatal development;

iii) the assumption, that under tropical conditions with plenty of sunlight DDT should have a much shorter half life, notwithstanding, there is increasing evidence for the persistence of DDT in water and soil;

iv) the long term effects of the continued presence of DDT residues in tissues and their ready mobilization whenever stored fat is mobilized and their inducing microsonal oxygenase activity on hepatic functioning are not known.

10.2 A Critique of Pesticide Residue Data

The assessment of the hazards to man arising from the very small quantities of a pesticide in food and the environment is an indispensable pre-requisite of the risk-benefit evaluation of pesticides. In most countries this is taken as an essential step before the pesticide is allowed to be introduced.

One of the most essential requirements for risk benefit analysis is reliable information on human exposure to pesticides. Such exposure estimates can be valid only when reliable methodology is used for getting data on residues in food, feed and the environment. Agencies concerned with risk benefit assessment and advising

Table 8 *DDT Levels in Food Products in India*

Food products 1	Concentration (ppm) 2	Year of sampling 3	Place of sampling 4	Reference 5
Butter				
Butter	0.68—0.75	1977	Rajasthan	Dhaliwal & Kalra 1978
Butter	0.35	1977	Delhi	„
Butter	0.81	1977	Ludhiana	„
Butter	0.04±0.14	1965	Pantnagar	Tripathi 1966
Butter	1.10—8.00	1974	Delhi	Agnihotri et al. 1974
Butter	1.62—2.54	1977	Gujarat	Dhaliwal & Kalra 1978
Butter	0.50—1.18	1977	Haryana	„
Butter	0.63—0.75	1977	Punjab	„
Butter	0.02	1977	Gujarat	„
Butter	0.70	1977	Ludhiana	„
Butter	0.57	1977	Ludhiana	„
Milk				
Milk	0.35		Izatnagar	Sastry & Singh 1978
Milk	0.0032±0.0026	1965	Pantnagar	Tripathi 1966
Milk	Traces—0.2	1969-71	Hyderabad	Lakshminarayan & Krishna Menon 1972 1971-72
Milk Toned	Not detectable	1972	Delhi	Agnihotri et al. 1974
Buffalo Milk	0.010—0.722	1979	Ludhiana	Kapoor et al. 1980
Buffalo Milk	0.011—0.800	1979	Jullundhur	„
Buffalo Milk	–	—	Lucknow	Saxena & Siddiqui 1982
Cattle Milk	0.019—1.09	—	Ludhiana (rural)	Dhaliwal & Kalra 1977
Cattle Milk	0.02—0.28	—	Ludhiana (urban)	„
Human Milk	0.127	1979	Lucknow	Siddiqui et al. 1981
Human Milk	—	—	Luchnow	Saxena & Siddiqui 1982
Human Milk	0.04—2 35	1979	Punjab	Kalra & Shawla 1981
Goat Milk	—	—	Lucknow	Saxena & Siddiqui 1982

Infant formula	0.63	1977	Punjab	Dhaliwal & Kalra 1978
Infant formula	0.40	1977	Bombay	
Infant formula	0.33	1977	Bombay	
Infant formula	0.26	1977	Gujarat	
Oils				
Groundnut Oil	5.0—7.14	1969	Delhi	Agnihotri et al. 1974
Mustard Oil	22.14—25.72	1969	Delhi	
Sesame Oil	10.0—12.14	1969	Delhi	
Coconut Oil	9.30—10.60	1969	Delhi	Agnihotri et al. 1974
Fats and Oil	1.3	1975-76	Calcutta	Mukherjee et al. 1980
Oil Seeds				
Groundnut	3.2—4.1	1969	Delhi	Thakare et al. 1969
Mustard	1.1—2.4	1969	Delhi	
Sesame	2.3—3.1	1969	Delhi	
Linseeds	1.7—2.4	1969	Delhi	
Condiments	0.7	1975-76	Calcutta	Mukherjee et al. 1980
Eggs				
Farm	18.5 ug/egg	1978-79	Lucknow	Siddiqui & Saxena 1983
Domestic bird	7.4 ug/egg	1978-79	Lucknow	
Egg	US FDA tolerance	1969-71	Hyderabad	Lakshminarayana and Krishna Menon 1971-72
Egg (shall free)	Not detectable to 0.24	1973	Delhi	Agnihotri et al. 1974
Egg	0.042	—	Izatnagar	Sastry & Singh 1978
Animal Products				
Goat	0.008—2.816	1979	Lucknow	Kaphalia & Seth 1981
Buffalo	0.011—5.038	1979	Lucknow	
Chicken	0.010—20.832	1979	Lucknow	
Chicken	0.005—0.670	1980	Luckn	
Pigeon	0.005—0.023	1980	Luckn	
Animal Product	1.5	1975-76	Calcutta	Mukherjee et al. 1980
Meat	1.39	—	Izatnagar	Sastry & Singh 1978
Fat	7.200		Izatnagar	Sastry & Singh 1978

(Contd.)

Table 8 (*Contd.*)

1	2	3	4	5
Fish	Traces	1969-71	Hyderabad	Lakshminarayan & Krishna Menon 1971-72
Fish	0.016—34.05	1979-80	Bombay	Bhinge & Banerji 1981
Mutton and Beef	US FDA tolerance	1969-70	Hyderabad	Lakshminarayana & Krishna Menon 1971-72
Food Grains				
+Wheat Flour	0.12±0.005	—	Punjab	Chawla et al., 1979b
+Chapatti	0.06±0.015	—	Punjab	
+Wheat Flour	0.57±0.010	—	Punjab	
+Chapatti	0.37±0.010	—	Punjab	
φWheat Flour	0.13	—	Punjab	
φChapatti	0.11	—	Punjab	
φWheat Flour	0 63	—	Punjab	
φChapatti	0.67	—	Punjab	
Wheat Flour	12-15	1958	—	Mitra et al. 1958
Wheat Grains	0.41±0.23	1965	Pantnagar	Tripathi 1966
Wheat Grains	0.05	1965	Delhi	ICAR 1967
Wheat Grains	4—6	1970	Ludhiana	Bindra et al. 1973
Cereals	Traces—0.8	1970-71	Hyderabad	Lakshminarayana & Krishna Menon 1972, 1971-72
Rice	9—16	1958	—	Mitra et al. 1958
Pulses	5—35	1958	—	Mitra et al. 1958
Pulses	Traces—0.5	1970-71	Hyderabad	Lakshminarayana 1973
Careals/Pulses	2.1	1975-76	Calcutta	Mukherjee et al. 1980
Vegetables				
Brinjal	0.08—0.80	1964	Ludhiana	Jaglan & Chopra 1970
Tomato	0.08	1964	Ludhiana	Jaglan & Chopra 1970
Animal feed and fodder	0.08—0.45	1976	Izatnagar	Sastry & Singh 1978
Vegetable	1.8	1975-76	Calcutta	Mukherjee et al. 1980

+Fresh weight basis

φDry weight basis

regulatory agencies on acceptable daliy intakes or permissible limits in foods need reliable residue data of treated crops and commodities and in water, soil, air, wildlife and other components of the environment.

The residue data in crops and food commodities can be classified according to the objectives in obtaining the data (Frawley & Duggan 1979, Bates 1979, 1981):

1. Radioactive labelled studies for identification of known chemicals or their metabolites.
2. Supervised trials where controlled use of pesticide in a crop is made and residue analysed.
3. Selective studies using known treatments.
4. Commodity monitoring where the treatments are unknown.
5. Dietary studies.

As one moves from 1 to 5 there is an increasing uncertainity in sample history. However, the information developed at level one can be progressively used in subsequent levels even though the information from individual levels is only of limited value. The three main objectives of residue studies are:

1. Estimation of maximum residue levels (given by 2 and 3)
2. Enforcement of Maximum Residue Limits (given by 4)
3. Assessment of consumer intake—made possible by 5.

10.3 Requisites for risk evaluation of pesticides

Three basic pre-requisites can be identified for assessing the significance of residue data in risk evaluation:

a) physical/chemical/biological properties of the pesticide.

b) reliable residue data from supervised trials or selective studies, and

c) toxicological data to estimate an acceptable daily intake of the pesticide.

In order to make a reasonable judgment, the residues left in a crop or commodity when the pesticide has been applied according to the recommendation for use, have to be presented on the above three items prior to registration. The registration authority uses such data to estimate the maximum residue level which might be expected out of a given use pattern. This estimate is normally based on data from supervised trials. The estimate itself may be used as a guide line level for what may be expected when the pesticide is used in the field. Out of this *Maximum Residue Limits* (MRL's) are derived for legal or regulatory action. MRL's lead to estimates of Admissible Daily Intakes. ADIs recommended by Codex Alimentanins Commission for 113 pesticidal chemicals are given in Table 9.

After a pesticide has been registered and allowed to be used, the competent authority should be able to confirm whether or not the estimate made at the time of registration was valid. When doubts arise, surveillance and monitoring studies have to be carried out. Enforcement programme of MRL's also generate information as a feed back to the regulatory agency for possible revision.

Table 9 *ADI's for commonly used Pesticides Codex (1978)*

Sl No 1	Alphabetical name 2	ADI (mg/kg body wt) 3
1	Aldrin and Dieldrin	0.0001
2	Azinmphose-methyl	0.0025
3	Bromophos	0.04
4	Binapaeryl	0.0025
5	Bromophos-ethyl	0.003
6	Captafol	0.01
7	Captan	0.10
8	Carbaryl	0.01
9	Carbon dilsulphide	—Not cleared toxicologically
10	Carbon tetrachloride	—Not cleared toxicologically
11	Carbophenothion	0.0002 (Temporary)
12	Chlordane	0.001
13	Chlordimeform	0.01 (Temporary)
14	Chlorofenvinphos	0.002
15	Chloromequat	0.05
16	Chlorobenzilate	0.02
17	Chlorpyrifos	0.001
18	Coumophos	0.0005 (Temporary)
19	Crufermate	0.1
20	2, 4-D	0.3
21	DDT	0.005
22	Diazinon	0.002
23	1,2—Dibromoethane	—Not cleared toxicologically
24	1,2—Dichloroethane	—Not cleared toxicologically
25	Dichlorovos	0.004
26	Dicofol	0.025
27	Dimethoate	0.020
28	Dioxathion	0.0015
29	Diphenyl	0.125
30	Diphenylamine	0.020
31	Diquat	0.008
32	Endosulfan	0.0075
33	Endrin	0.0002
34	Ethion	0.005
35	Ethoxyquin	0.06
36	Fenchlorfos	0.01
37	Fenitrothion	0.005
38	Fensulfothion	0.0003

Table 9 (*Contd.*)

1	2	3
39	Fenthion	0.0005
40	Fentin	0.005
41	Folpet	0.16
42	Formothion	0.02
43	Heptachlor	0.0005
44	Hexachlorobenzene	0.0006
45	Hydrogen cyanide	0.05
46	Hydrogen phosphide (Phosphine)	—Not necessary—good usage practice ensures no residues
47	Inorganic bromide	1.00
48	Lindane (γ-BHC)	0.01
49	Malathion	0.02
50	Mancozeb	0.005
51	Methiodathion	0.005
52	Methyl bromide	—Not cleared toxicologically
53	Moceinphos	0.0015
54	Monocrotophos	0.0006
55	Omethoate	0.0005
56	Ortho-phenylphenol	1.0000
57	Paraquat	0.002
58	Parathion	0.005
59	Parathion-methyl	0.001
60	Phosalone	0.006
61	Phosphamidon	0.001
62	Piperonyl butoxide	0.03
63	Pyrethrins	0.04
64	Quintozene	0.007
65	Thiabendazole	0.300
66	Trichlorfon	0.005
67	Cyhexatin	0.007
68	Azinphos-ethyl	—Not cleared toxicologically
69	Benomyl	—Not cleared toxicologically
70	Bromopropylate	0.008
71	Camphechlor	—Not cleared toxicologically
72	Carbendazim	—Not cleared toxicologically
73	Dimeton-s-methyl	0.005
74	Disulfoton	0.002
75	Propoxur	0.02
76	Thiometon	0.005

Table 9 (*Contd.*)

1	2	3
77	Thiophenate-methyl	0.08
78	Vamidothion —Not cleared toxicologically	
79	Amitrole	0.00003 (conditional)
80	Chinomethionat	0.003
81	Chlorothalonil	0.03
82	Dichloflucenid	0.3 (Temporary)
83	Dichloran	0.03
84	Dodine	0.01
85	Fenamiphos	0.0006
86	Pirimiphos-methyl	0.01
87	Dinocap —Not cleared toxicologically	
88	Leptophos	0.001
89	Lec-Bulylamine	0.2 (Temporary)
90	Chloropyrifos-methyl	0.01
91	Cyanofenphos	0.005
92	Dimeto	0.005
93	Bioresmethrcin —Not cleared toxicologically	
94	Methomyl —Not cleared toxicologically	
95	Acephate	0.02
96	Carbofuran	0.003
97	Cartap	0.05
98	Dialefos	0.003
99	Edifenphos	0.003
100	Methamidophos	9.002
101	Pirimicarb	0.004 (Temporary)
102	Maleic hydrazide —Not cleared toxicologically	
103	Posmet —Not cleared toxicologically	
104	Diminozide —Not cleared toxicologically	
105	Dithiocarbamates	
	Dimethyl..(Ferbam, Thiram, Ziram)	0.02
	Ethylene bis.. (Mancozeb, Maneb, Zineb)	0.005 (Temporary)
	Propylene.. (Propineb)	0.005 (Temporary)
106	Ethephon —Not cleared Toxicologically	
107	Ethiofencarb	0.10
108	Ethylene thiourea —Not cleared Toxicologically	
109	Iprodione	0.3
110	Fenbutatin oxide	0.03
111	Imazalil	0.01 (Temporary)
112	Phorate —Not cleared Taxicologically	
113	Propargite	0.08

The entire mechanism for this implementation in an ideal regulatory system is shown in Figure 4. The situation in India is obviously far from any realisation of this ideal situation.

10.4 Expertise in Analytical Chemistry and Quality Assessment of Data

The IUPAC Commission on pesticide chemistry prepares reports on the status of clean-up and determination procedure and confirmatory techniques and describe current and projected applications of analytical principles and equipment to pesticide residue analysis. In order to make meaningful use of these guidelines there is need for a network of analytical laboratories with an in-built system for the quality assessment of the analytical data. The Food Laboratories which carry out analysis for pesticides on foodstuff in many of our states are today hardly equipped either from the point of view of instrument infrastructure or from analytical expertise to produce high quality data which can be used for determining national MRL's. These deficiencies have to be overcome.

10.5 Perspectives

At present it is frustrating to make separate estimates of the contributions made by the use of pesticides in vector control in public health as distinct from the contribution of pesticides in plant protection towards the accumulation of residues in foods and biological tissues (Youdeowi & Servia 1983). It is however relatively easy to get information on the type of chemicals and their quantities used for vector control in public health as most of the operation is conducted by government agencies. Pesticides

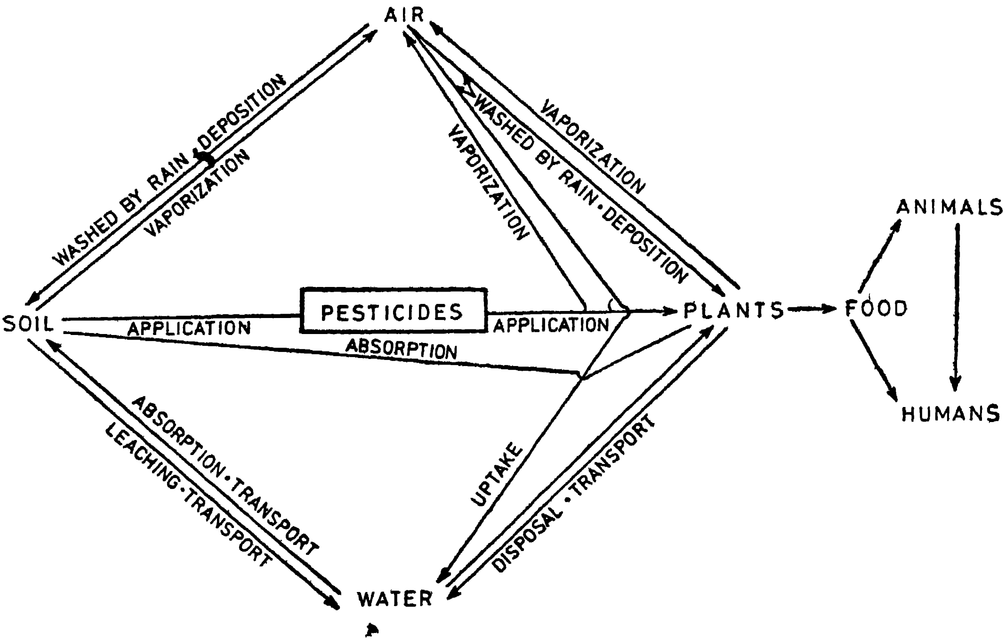

Figure 4 Pesticide Application & Cycling in the Environment

used in agriculture vary from crop to crop and from season to season (Weir & Schapiro 1981). There has been no attempt so far to document the exact use pattern in agriculture excepting the sales data of companies which market the chemicals and inventories of Government depots which distribute the chemicals to farmers. It is believed that weedicides are mainly used in the planation crops of tea and coffee. However, there are unofficial reports of the increasing use of weedicides by farmers in the control of weeds in rice and wheat cultivation in Punjab and Haryana.

There is an urgent need to monitor the use pattern and evolve guide lines for "good practice" in the use of pesticides in agriculture. Here is a field of use where chemicals become obsolete very quickly due to ineffectiveness and hence the need for substitutes in frequent succession. The guidelines outlined by the Codex Alimentanins Commission and given in 'Appendix I' can be used as a model document for spreading the culture of "good agricultural practice" among our farmers.

Above everything else, in broader national interests, professionalism sustained by constantly updated inputs of inter-disciplinary expertise has to replace the amateurism rampant in the advisory bodies attached to Ministries/Departments concerned with the overall safety of pesticides.

APPENDIX I

Guidelines on the use of Pesticides in Agriculture

(From Codex 1958)

1. Purpose of the Guidelines

Indicate principles for the use of pesticides in agriculture and in the harvesting, marketing, transport and storage of foodstuffs. The following factors have to be taken into consideration while identifying the goals aimed at in good practice in the use of pesticides:

a) attainment of the desired degree of control of pests at an economic cost, and

b) a minimum of danger to operators, agricultural workers, consumers, beneficial animals and the environment.

2. General

i) If pesticides reach humans or animals through different routes and thus give rise to additional body loads, the use patterns may have to be adjusted, and, if necessary, priority should be given to those uses which are indispensable and for which no adequate alternatives are available.

ii) Maximum residue limits established for products for human consumption are not necessarily acceptable for the same product when this is destined for animal consumption and vice versa.

iii) In view of the necessity of preserving a balance between cost, productivity, quality and freedom from residues the concept of good agricultural practice in relation to pesticide residue embraces all interrelated and essential factors and function, which ensure that the pests will be controlled effectively, leaving residues that are the smallest amounts practicable and that are all toxicologically acceptable.

iv) Pest control treatments should only be made when necessary. The requirements for pest control should first be established, followed by the application of the preferred method of control.

3. Choice of Pesticides

i) All pesticides used should be registered by appropriate agencies (in India the Pesticides Registration Committee of Central Insecticide Board). They should only be marketed with lables indicating recommended or approved uses, times, methods and rates of application, and safety precautions for the user. Such recommended methods of application should be based on supervised trials and other experimental work, and should take into account such variations in climate, in crop husbandry, and in incidence of pests as may occur under practical conditions from time to time in the places where the pesticide is applied.

ii) The pesticide should be adequately safe to humans and the environment and at the same time provide adequate pest control.

iii) Where a choice of pesticides is available, the cost and effectiveness of available pesticides should be weighed against the risks involved, and those which show a more favourable benefit-risk ratio for the particular purpose in question should be preferred.

iv) When pest control is required in the early growing stage of the crop, a pesticide may be needed which has an adequate and acceptable degree of persistence, in order to avoid repeated applications of non-persistent pesticides.

v) Where plant guarantine and/or phytosanitary requirements make it necessary to apply pesticide close to or after harvest, those which have a short persistence should be preferred.

vi) The agricultural use of persistent and/or cumulative pesticides on crops for human consumption should be restricted as much as possible, and be limited to the control of pests, weeds and diseases for which at present no suitable alternative chemicals are available.

vii) As a general rule, persistent and/or cumulative pesticides on crops for human consumption should not be used on fodder crops and not be applied directly to animals for veterinary purposes.

viii) Where post-harvest treatments are required, pesticides which leave residues that are the smallest amounts practicable and toxicologically acceptable, do not interact with the food commodity, and/or are readily removed during storage, preparation or cooking, should be preferred.

ix) With respect to post-harvest treatment of stored products (e.g. cereal grains) it is recommended not to use persistent and cumulative pesticides as direct admixture.

x) The application of adequately durable pesticide to the exterior of packing material for stored products is acceptable, but the use of highly persistent and cumulative pesticides should be avoided as much as possible,

4. Choice of Formulation

i) Formulations which combine maximum efficiency of the pesticide with maximum risk should be preferred.

ii) Supplementary adjuvants should be used only if their effects, including toxicological effects, are known and where their use produces a significant improvement in performance.

iii) In general the use of combined pesticide/fertilizer formulations should be avoided.

5. Dosage

i) The quantity of pesticide applied should not be greater than the minimum required to achieve the desired degree of control.

ii) The number of treatments should be determined by the desired degree of control and by the severity of pest conditions.

6. Applications

i) The method of application should be selected to ensure optimum pest control with the minimum contamination of the crop and the environment.

ii) Indirect treatment (such as application to the soil, seed dressing, fumigation of empty silo cells, treatment of alternate hosts) can, in some cases be used to supplement or replace direct application to food crops.

iii) Application equipment should at all times be maintained and used according to the makers' instructions.

7. Timing of Treatment

i) Treatment should preferably be carried out when the pests are at the most vulnerable stage of development, and when climatic conditions and cultural practices will ensure that the optimum effect can be attained from the treatment. In some instances, however, action may be necessary immediately following detection in the pest species.

ii) The interval between last application and harvest should be as long as possible in order to permit the greatest reduction in pesticide residues, bearing in mind the pest incidence, the degree of control required for a maximum utilization of the commodity, and the vulnerability of the treated crop immediately pre-harvest. To this end official pre-harvest intervals should be established and adhered to.

8. Post-treatment Practice

i) Crop rotation should be adjusted in such a manner that uninternational residues in the edible parts of the crop, as a result of previous treatments, will be minimal, particularly if the crop may be used as animal feed, and accumulation in the animal body may lead to undue residue in food products of animal origin.

ii) Seed-grain, treated with pesticides at dosages to provide long-term protection in the soil, must, under no circumstances, be mixed with commodities destined for human or animal consumption. Sufficient safeguards ought to be provided which would minimize the accident risk of such practices.

iii) Where grain intended for consumption must be protected in storage, only compounds with low chronic toxicity and/or short persistence should be used.

iv) In the storage practice, the selection of the pesticide for treatment of empty wharehouses or ship holds and the subsequent storage arrangements should be such that there is a minimum risk of contaminating feed or food products.

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